This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

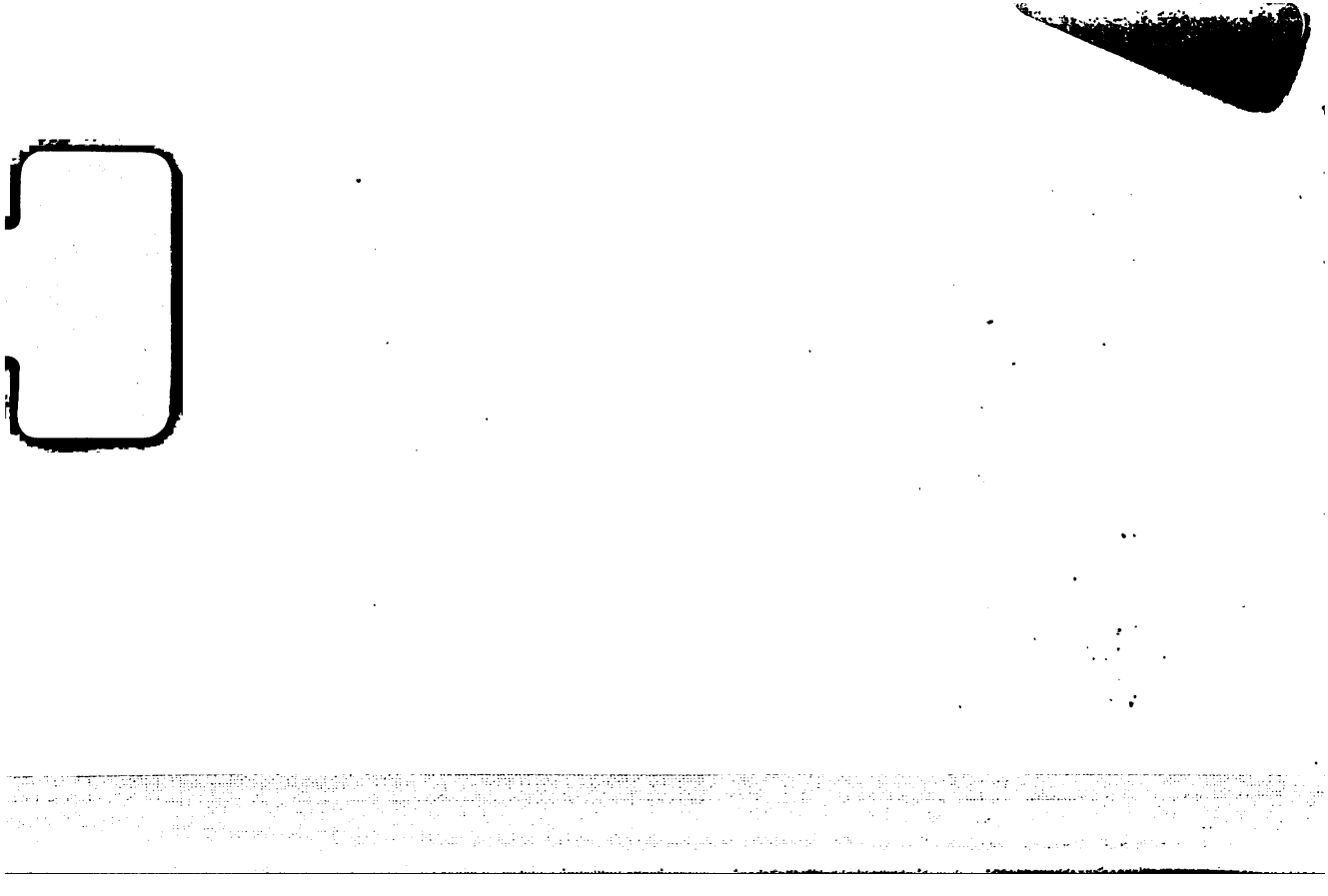
+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

NYPL RESEARCH LIBRARIES
3 3433 06637410 3

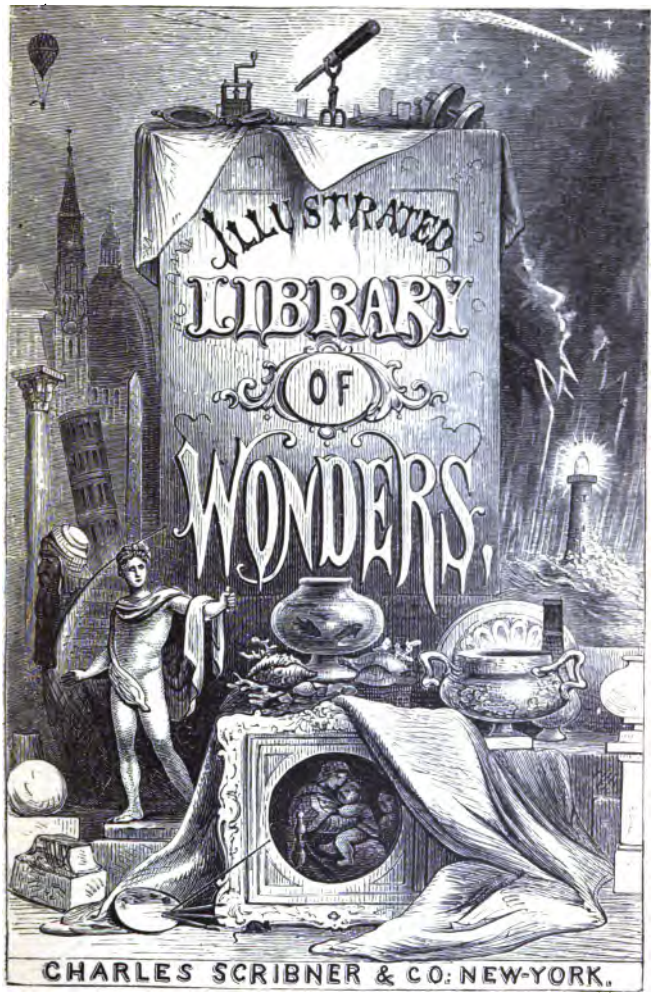


1 Electricity, 1872

2. Electric express, 1876

[illegible]

VGC


ILLUSTRATED
LIBRARY
OF
WONDERS.
CHARLES SCRIBNER & CO: NEW-YORK.

AERIAL TELEGRAPH. See page 12.

WONDERS

OF

ELECTRICITY

TRANSLATED FROM THE FRENCH OF

J. BAILE.

EDITED,

WITH NUMEROUS ADDITIONS,

BY DR. JOHN W. ARMSTRONG,

PRESIDENT OF THE NEW YORK STATE NORMAL SCHOOL, FREDONIA, NEW YORK.

With Sixty-five Illustrations.

R LIBRARY

NEW YORK:
SCRIBNER, ARMSTRONG, AND CO.,
SUCCESSORS TO
CHARLES SCRIBNER AND CO.
1872.

Entered according to act of Congress, in the year 1872, by
SCRIBNER, ARMSTRONG, & COMPANY,
In the office of the Librarian of Congress at Washington.

RIVERSIDE, CAMBRIDGE:
PRINTED BY H. O. HOUGHTON AND COMPANY

CONTENTS.

PAGE

INTRODUCTION 1

BOOK FIRST.

CHAPTER

ELECTRIC TELEGRAPH.

I.—Preliminary Remarks 9
History of the Telegraph 10
Speed of Electricity 15
Action of Electricity in Telegraphs 17
The Battery 19

II.—Morse's Telegraph—Electro-magnetism 23
Aerial Circuit 31
The Receiver 33
The Manipulator 38

III.—Different Instruments employed in Telegraphy—Relays 42
Translators and Transmitters 45
Bells 46
The Lightning-rod 48
Compasses and Galvanometers 53
Batteries 56

IV.—Railway Telegraphs—Preliminary Considerations 68
Receiver of the Dial Telegraph 71
Manipulator of the Dial Telegraph 75

CHAPTER PAGE

Installation 78
Signalling Apparatus 82

V.—Construction of Telegraph Lines 92
Stations 101
Subterranean Lines 103
Submarine Lines 106

VI.—Other Telegraphic Systems 118
The Perfected Morse Telegraph 119
Mr. Hughes's Telegraph 123
M. Caselli's Autographic Telegraph 129
The Acoustic Telegraph 140
The Future of the Telegraph 143

VII.—Applications of the Telegraph—Miscellaneous applications 149
Applications to Military Operations 151
Semaphoric Services 154
Electric Clocks 156

BOOK SECOND.

INDUCTION MACHINE.

I.—Coil of Ruhmkorff 159
Of Induction 160
Induction Coil 166
Ruhmkorff Coil 170
Effects obtained 176

II.—Various Uses 186
Rarefied Air Machines 187
Public Illumination 189
Small Machines 193
Clarke's Machine 194
Magneto-electric Telegraph 198
Electro-medical Machine 202
Electric Baths 206

III.—Electric Motive Powers 210
Nature of a Motive Power 211

CHAPTER PAGE

Description of Electro-motive Power Machines 213
Conditions of an Electric Motive Power 219
Of the Battery 221
Transformation of Forces 224
Application of these Principles to Electric Motive Power 228
Some Machines moved by Electricity 231

BOOK THIRD.

ELECTRIC LIGHT.

I.—The production of Light 237
Of the Voltaic Arc 238
Photo-electric Regulators 241
The Carbon Points 245
The Magneto-electric Machine 248
Lighthouses 252

II.—Applications of the Electric Light—Coloration of the Voltaic Arc 260
Photo-electric Microscope 264
Illuminating Night Works 265
Public Illumination 268
Lighting of Ships 270
The Electric light in the Theatre 271
Luminous Fontains 275
Phosphorescent Bodies 277
Drummond Light 278

BOOK FOURTH.

ELECTRO-PLATING.

I.—Gold Plating—History of Electro-plating 281
Preparation of the Articles 283
Baths of Gold 285
Machinery employed 287
Finishing Operations 289

CHAPTER PAGE

Silver Electro-plating 291
Reserves 295
Uses of Galvanic Gold-plating 296
Ancient Processes 299

II.—Galvanic Copper-plating 301
Machinery 302
Moulds 303
Massive Galvano-plating 306
Galvanoplastic Statuary 307
Different Reproductions 311
Manufacture of Candelabra 312

III.—Different Uses of Electro-plating 315
Galvanic Engraving—Daguerrotype Plates 318
Conclusion 319

APPENDIX 323

LIST OF ILLUSTRATIONS.

	PAGE
Aerial telegraph	*Frontispiece.*
Elements of the voltaic pile	7
Electro-magnet loaded with weights	27
Telegraphic electro-magnet	29
Insulator	31
Receiving apparatus	34
Paper band	35
Morse's manipulator	39
Froment's relay	43
Theory of the relay	44
The bell	47
Lightning-rod	51
Ordinary compass	54
Daniell's battery, disconnected and in action	60
Davy's battery	63
Theoretical section of a battery	66
Anchor escapement	72
Dial receiver	73
Telegraphic dial	74
The dial manipulator	77
Railway conductor sending signals	80
Railway indicator	83
Monitor	85
Bell-shaped insulators	94
Other forms of insulators	95
Joining the wires	96

PAGE

Tension ratchets 97
Stretching the wires 97
Morse-telegraph station 96
French railway telegraph station 102
Section of a submarine cable 111
Lair's method of connecting cables 116
Theoretical diagram of Hughes's telegraph 124
Explanation of the axes 127
Fac-simile of a design transmitted by Caselli's apparatus 133
Caselli's transmitter 134
Caselli's pantelegraph 136
Induction of one wire by another 161
Induction of a wire by a magnet 162
Small Ruhmkorff coil, with a vibrating insulator 174
Large Ruhmkorff coil, with a counterpoise 175
The Holtz electric machine 179
Cube of glass shivered by electricity 182
Uranium-glass vase 184
Electric gas-lighter 190
Clarke's machine 195
Electric chain 204
Pulvermacher's chain 205
Ruhmkorff's electro-medical machine 205
Electric bath 207
Bourbouze's electro-motive power machine 215
Froment's electro-motive power machine 216
Bunsen's battery 221
Pump moved by electricity 233
Archereau's regulator 243
The Alliance Company's magneto-electric machine 252
Théâtre de l'Opéra, Paris: Opera of *Moses* 270
Another scene from *Moses* 274
Luminous fountain 276
Battery for silver-plating 288
Statue of Henry IV. reproduced by galvanoplasty 310
Page's induction machine 327

WONDERS OF ELECTRICITY.

ELECTRICITY.

INTRODUCTION.

So recently as a century ago electricity was regarded as a subject of mere curiosity and amusement. Numerous facts had been ascertained concerning it, but they were isolated one from the other, and had not been combined into a system. The electric machine of that day was only used to repeat experiments, which seemed extraordinary in proportion as they were not understood. Men of fashion as well as savants begged the favor of being admitted to those places where electrical experiments were conducted. The Abbé Noblet, Dufay, the superintendent of the Royal Garden, and many others, who, varying continually the form of their experiments, discovered new facts in connection with the science, were accustomed to hold assemblies of their friends, in order to investigate the subject. These meetings took place in a large, empty, and half dark chamber.

There, strange and mysterious apparatus fixed their attention; while, with most minute precautions

and in breathless awe, they discoursed upon electricity.

Here was taught the doctrine that all objects, including the human body, could give out sparks of fire; and, by way of practical exemplification, an electric shock was given to the whole assembly—a shock which was more or less violent, and which was compared to the effects of lightning. When these neophytes of science withdrew from these assemblies, marvelling at the things they had seen, their excited imagination magnified the phenomena, and their minds were carried away by vague and confused notions. About the same time, among the multitude outside, superstitious beliefs began to spread. Mesmer, Paris, the deacon, and Cagliostro astonished both town and court with their miracles.

At length at one of these private scientific reunions, the patrons of electric experiments discovered a singular fact, which was followed by the most splendid results. The discovery was made at Bologna, in the year 1790, in the laboratory of Galvani, professor of anatomy in the University of that city. That savant happened to be subjecting frogs to a critical examination, and a number of these reptiles divested of their skins lay on the table of the electric machine.

They were drawing sparks from the machine, it is said, and one of the spectators, in connection with the machine, accidentally touched one of the prepared frogs with the point of a scalpel which he held in his hand. What was the astonishment of the assistants when they saw the muscles of the

dead and skinned animal agitated with violent convulsions ?*

Galvani's attention was immediately drawn to the subject, and he forthwith began to examine the causes of the phenomenon, and to inquire into the conditions under which these singular shocks took place.

Any experimentalist acquainted with Dr. Franklin's theory of lightning would have immediately understood the phenomenon that so greatly astonished Galvani, and thought no more about the matter. But Galvani was essentially an anatomist, and accustomed to prove things to the core. He did not understand what is known as the "return shock," and his ignorance proved of the greatest use to science and to posterity; for in order to understand what he had observed he pursued the study of the new phenomena with earnestness, and in the pursuit obtained such a number of new facts as to form the science, or department of science, which, after its discoverer, has been called Galvanism.

He wished, in the first instance, to ascertain the action of the electricity of the air upon animal organisms. One day, the sky being cloudy, he suspended a skinned frog from his balcony. This balcony was made of iron, and Galvani made use of a copper wire to fasten the reptile. His astonishment was unbounded when he saw the muscles of the

* Such is one version of this interesting anecdote. It would be a pity to spoil it at the command of that inexorable goddess, Truth. Perhaps, after all, touching the frog was not accidental.—A.

dead body contracting violently as soon as they touched the iron of the balcony. Thus he became aware of the fact that without any apparent production of electricity, but by bringing merely the frog, suspended by a copper wire from the balcony, into contact with the iron railing, muscular contractions took place, much more violent than were produced when the charged scalpel touched the dead frog on the electric machine. At the news of this experiment all Europe shared the surprise and emotion of the professor of Bologna, and it was everywhere felt that from this ascertained phenomenon some great discovery would soon result.

Scientific men set themselves to work in order to achieve something in this direction. They repeated the experiment, and sought to find its explanation. Galvani asserted that the muscles and the nerves of animals are reservoirs of the electric fluid. "Isolated in these organs," said he, "the fluids can combine only when a metallic circuit offers them passage, and it is this combining of the fluids that produces the shocks." Physiologists applauded this theory. They fondly imagined that the mystery of life was explained; and that electricity was the agent that transmitted the will to the muscles. Seductive hypotheses were built up which dazzled the mind with words devoid of sense, but vanished as soon as they were tested by reason.

Galvani's experiments can easily be repeated. Remove all the upper part of the animal, leaving only the hind legs, with a portion of the spine. In flaying the lumbar portion and legs, you expose the

lumbar nerves, two whitish threads, which follow the vertebral column. Provide an arc, having one branch of copper and the other of zinc, connected by soldering or twisting. With one extremity of the arc touch the lumbar nerves, and, while in contact, touch with the other end the muscles of the thigh; at each contact the muscles contract, and the legs are agitated, as if they still retained life and could jump about.

Galvani in his explanation only took into account the nerves and the muscles; the metallic circuit he held to be only accessory. A professor of Pavia, Alexander Volta, found out, as Galvani himself had already done, that the contractions were very feeble when the circuit or arc employed consisted of a single metal. He therefore attributed the development of electricity to the contact of two different metals, or at least the contact of the metal with the nerve or the muscle. He maintained that when two different substances of whatever kind come into contact, there is a development of electricity, and that the dead frog serves only to manifest this development.

A memorable controversy took place upon the subject between the two savants. Each upheld the truth of his own explanation of the phenomena, and endeavored to support it with new facts. Volta's theory, it has since been found out, was no nearer the truth than Galvani's. The result of their battle was not to the advantage of either of the combatants, but immensely to the advantage of the lookers-on. Both fought well, but posterity alone gained

the benefit. Volta, in order to sustain and bear out his theory, which was really a misconception, invented the instrument which has since become known as the voltaic pile—an instrument which, of all electric machines, has perhaps been the most prolific of results.

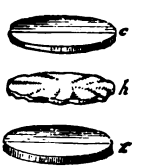
In the building up of his theory his mind was absorbed by that one idea, and dwelt upon it without cessation, seeking the means of confirming his assertions by conclusive proofs. In the course of his investigations he was puzzled by a fact of which he could not give any explanation. He had placed two discs in contact, one of zinc, the other of copper, and upon each of these metals he had recognized the presence of electricity, but both exhibited electricity of the same kind, while, according to his theory, they should have exhibited electricity of different kinds.

One day, as he tells us in his letters, he was reading in a Roman newspaper an account of the ceremony observed at the election of a pope. In spite of himself he could not fix his attention upon the narrative, his thoughts returning continually to the inexplicable and unaccountable phenomenon which had previously puzzled him. Mechanically having torn off a corner of the paper and placed it to his mouth, the fancy struck him of employing this bit of wet paper in the realization of his experiment. Yielding to this inspiration, he took his discs and placed the wet paper upon the apparatus which served to indicate to him the nature of electricity. No sooner had he done this than he found

that the difficulty was conquered; each of the metals was electrified in a different manner.

He then understood his error. In order to find out the electricity of a disc, he had heretofore placed it in contact with brass made of copper nearly pure. The copper touching this brass, two similar substances were in contact; the zinc touching the brass the two metals were different. Volta thus found himself confronted with facts which he had formerly believed did not exist, and by results the opposite of those he had expected. In touching the brass by the intermediary wet paper, he did not introduce a third metal into the series, and therefore found himself again in the condition demanded by his theory.

From this time the voltaic pile or battery may be said to have been invented. Volta took a series of two discs, one of copper, (*c*,) and one of zinc, (*z*,) soldered together. He separated each compound plate with a circular piece of woolen cloth, (*h*,) moistened with a solution of common salt or diluted sulphuric acid, and placed these above each other in a *pile*. The quantities of electricity which he drew from this machine were sufficiently great to produce shocks and even sparks. These effects were obtained continuously, and there was no need of recharging the pile continually, as we have to do with the electric machine.



Elements of the Voltaic Pile.

When an apparatus furnishing electricity hourly under all circumstances, and in a regular and con-

tinuous manner, had thus been found, the study of electric phenomena became at once more easy and simple. The pile was perfected almost from the first, and subsequently innumerable results, which fill us even at the present day with admiration, were obtained from it.

Now if we consider the advance that has been made within the last seventy years, since the invention of the voltaic pile, and contemplate the onward line of progress marked out for us in the future—if we think on the works that have already been accomplished, and those which have become possible—if we reckon up all the discoveries which time alone is required to develop, and which the generations that succeed us will profit by, we cannot fail to experience a feeling of gratification. A sentiment of pride overcomes us when we think of this triumph of human intelligence. By such discoveries the most completely concealed secrets of nature are revealed, and the most redoubtable and most mysterious of nature's agents, the lightning itself, is at length partially conquered, and made subject to the wants and services of mankind. Strange indeed, is it, to think that the most terrible force of nature is also the most pliant and the most valuable for the many purposes to which it can be applied. In view of these great results, all the little happy chances which brought them to pass are forgotten. We no longer remember the contest between the two creators of this part of the science, but only contemplate the immense benefit with which they have endowed mankind.

BOOK FIRST.

ELECTRIC TELEGRAPH.

CHAPTER I.

PRELIMINARY REMARKS.

In all times men have desired to communicate with each other through space. The traveller, far from his family, desires to inform them of his welfare from day to day; the invalid wishes to call to his bedside the masters of medical science from distant capitals; the merchant, ever watchful over his particular interests, seeks to know the prices of foreign markets; the magistrate and the general who have to regulate their conduct by events that take place at a distance, are solicitous to obtain the earliest and most correct information. More and more clearly, as human activity increases, we perceive the necessity of perfecting our means of communication with places at a distance. Already the electric telegraph affects our daily habits, regulates our business, enters largely even into our

social life, and ministers hourly to the wants and necessities of mankind. What was formerly an expensive luxury, used at rare intervals by the wealthy, has become familiar to all, and is employed upon a scale and with a success which would have appeared impossible to our ancestors. In enumerating all the applications of the telegraph, it is with difficulty we conceive how the human race could get on during so many centuries without having discovered it, and we read with a sort of curiosity the history of the imperfect means of correspondence with which our fathers were content.

HISTORY OF THE TELEGRAPH.

Among the Gauls, when one had an important piece of news to transmit to a distance, a young man went up to the top of a hill, and from this elevation shouted his message to all the points of the horizon. His words were literally borne on the wings of the wind. Soon from a distance a voice answered him, and thus from mouth to mouth the news travelled to the extremities of the country; across mountains and plains, and through Druidic forests, in silence and in darkness, the voice was heard rising in the air. Cæsar assures us that this mode of transmission was very rapid. He tells us that it required hardly three days for a message which called all the tribes of Gaul to arms, to travel from Auvergne to the sacred forests of Amorica and the marshes of the Rhine. But if this me-

thod of transmitting messages was rapid, it was hardly safe; for the Romans would of course learn the import of the message in the course of its transmission. The Gauls, however, did not trouble themselves about this, for they regarded it as dishonorable to take advantage of an enemy, and so far did they carry this chivalrous notion, that it is said they attached bells to their arms to announce their approach. Other means of communication were from time to time made use of by different nations. Fires lighted upon elevations formed, by their arrangement, signs by which the meaning of the message could be understood. Æschylus describes an old servitor of Agamemnon mounting each evening upon the walls of Argos, to watch the first of the distant fires which should announce his master's return. A signal fire upon Hero's tower lighted Leander across the rough waters of the Hellespont. In the Middle Ages, we read that the fiery cross shone all along the British coast, thus announcing the approach of the Normans, and warned by this signal, the archers and the Saxon monks spread themselves throughout the country and informed the thanes what the quarrel was, for which they were to arm. At the sign of the fiery cross, borne by fleet clansmen through the glens and passes of the Scottish highlands, the plaided warriors gathered to the sound of the pibroch and marched at the bidding of their chiefs. Indeed, from its convenience and suitableness, this mode of conveying news of war commended itself to nations the most widely separated, and, according to travel-

lers, the savage tribes of Asia and of Central Africa make use of it as the most convenient agency for this purpose.

Such a mode of transmission, however, could necessarily only apply to a very limited number of messages. So long as the people of the Middle Ages lived in isolated groups around their towns, not much affected by general and distant interests, they scarcely felt the necessity of communicating with one another across great distances. But when manners changed, when men began to gravitate to the idea of national unity, other modes of communication became absolutely essential. Emissaries of various kinds were then employed. Sometimes pigeons trained to carry letters were used as messengers. At other times courageous and faithful servants were charged either with letters, or simply with verbal messages, the men so employed being well informed in all the details of the important affair, and made familiar with certain signs previously arranged. Latterly, Louis XI. organized the system of signal posts in France, and this simple mode of communication, transformed and modified to meet the increasing wants of different ages, was for a long time sufficient for all purposes of transmission. Our ancestors admired, with good reason, every improvement in the mode of communicating information through the medium of telegraph posts, and by means of letters dispatched by the hands of messengers. Things were considered great feats in those days which we would regard in a quite opposite light. Couriers took a whole week to traverse dis-

tances which are now performed in a single day. For instance, at the end of the 16th century, the news of the death of Henry III., the last of the Valois, only arrived fifteen days after the event at Marseilles, which, forming a portion of the League, had the keenest interest in hearing the news at the earliest possible moment. At the present day a letter takes only sixteen hours to go from Paris to Marseilles, and a telegram can be sent in a few minutes.

Whilst noticing the rudest methods of sending messages, we must not omit to mention another means of transmitting intelligence which preceded the invention of the electric telegraph, namely, the aerial telegraph, which many still living have seen in operation.

It was in 1793 that Claude Chappe, after many fruitless attempts, succeeded in establishing a telegraphic line from Paris to Lille. On the 30th of November, 1794, the first dispatch announcing the capture of Condé by the Austrians, arrived in Paris. The Convention was then sitting, and immediately sent back the message; "The army of the north has deserved well of the country." The soldiers received this flattering eulogy a few minutes after their victory. Such a happy announcement assured the success of the new system. It was organized immediately afterwards on a scale so complete that for a long time after the institution of the electric telegraph, although the latter had been adopted in the whole of Europe, France could not resolve altogether to abandon the use of the aerial telegraph.

Upon a rising ground in the country, or on some eminent part in towns, great towers were erected, surmounted by movable turrets which could be turned toward any part to which it was desired to send a message. Above the tower were two long, black, movable arms, connected by an immovable bar. The motions of the black arms, which could be made to move in various ways, were so many signs which represented words and complete phrases. So long as the skies remained clear the signals were visible from a distance, but this essential condition did not prevail in all seasons. Often, in the midst of an important dispatch, mists would arise and the gloom thicken, the signals would become more and more obscure, and the conductor, who glass in hand translated the dispatch, had to leave it in an unfinished state, concluding it with the dismal words: "stopped by the mist."

Before they became of practical use in the service of industry, electric telegraphs were considered merely as parlor curiosities. The system most generally adopted (Professor Morse's) dates from the year 1831. At this time the machine was very nearly as perfect as it is at the present day, and yet the inventor had to wait and to labor for eight years before he succeeded in getting his invention seriously considered by the public.

At the present time we may well be astonished at the doubts and delays with which the electric telegraph was at first received. It would seem to be a law of our nature to regard as merely chimerical whatever is an innovation on our habits, or not con-

tained in the list of our preconceived ideas. Perhaps even we of a later time also treat admirable inventions, which will appear very simple to future generations, with the same obstinacy and contempt as our forefathers regarded the mechanical wonders which seem to us as simple as they are useful. Some excuse for this is undoubtedly to be found in the fact that it is very difficult to examine all the discoveries that emanate from the brains of inventors. How is it possible to investigate and weigh them all? Where should we find time and money in sufficient quantity? Inventions are great in number, and decisive experiments are costly.

Electric telegraphy had to pass through a long and neglected childhood—perhaps other discoveries in their turn must wait their time for recognition. There is, for instance, autographical telegraphy, which offers to transmit the very handwriting of correspondents; and acoustic telegraphy, which pretends to convey even the accent of the speaker, so that by its means two people can talk across space as if they were in the same room—and other inventions at present neglected which may not always be so. There are innumerable projects undergoing a process of maturing. Who can foresee all the surprises reserved for the future?

SPEED OF ELECTRICITY.

No known speed in the world can be compared with electricity. It is in truth difficult to convey any precise idea of what is perhaps a speed of 200,-

000 miles per second. Suppose a vast telegraphic wire setting out from one pole, passed over the opposite pole and returned again to the point whence it started—suppose, further, that this wire, without a break, made the circuit of the earth twice: a signal given at either end, would run the entire length to the point of departure, in less than a second, or in the brief space that intervenes between two beats of the heart. In a word, it would take less than a second for electricity to make the entire tour of the globe twice. Other examples might be given. A cannon ball, for example, flying at the speed with which it travels at the instant of projection from the cannon, would take 21 hours to go round the world, whilst a locomotive going at full speed, would take 17 days to clear the space traversed by electricity in less than half a second.

There are means of comparison, perhaps, even more astonishing. The sun is so far from the earth that its light takes eight minutes to reach us; electricity could traverse the distance in about the same time. But it would take 10 years for a cannon ball, 15 years for sound, 200 years for a steam engine, and 2,000 years for a man walking night and day, and never stopping for rest, sleep, or refreshment, to traverse the same distance. It therefore seems that the speed of electricity is almost infinite. If despatches sent by means of it do not arrive instantly at the place of their destination, if the transmission exceeds a certain time, we must not accuse the electricity itself, but the exigency of the service, the manifold circumstances which accompany the dis-

patch and interfere with the regularity of the signals. From recent investigations we are led to believe that in time we will attain to a much higher degree of speed in the transmission of messages.

ACTION OF ELECTRICITY IN TELEGRAPHS.

In order to make electricity carry a message from one locality to another, it is necessary to set in motion certain machines which produce a number of signals. These signals the telegraphic clerk knows how to interpret into a message.

A telegraphic machine may be compared to a water-wheel, and the action of the electricity to that of the water. A sluice is opened, the water rushes into a canal provided for it, traverses the canal, and falling upon the wheel acts upon it by its weight or its momentum, turns the wheel, and having thus effected the purpose for which it was intended, escapes downwards. Meanwhile the wheel, by the revolving motion which the water has given it, moves the machinery of the factory or mill to which it belongs, and thus fulfills its purpose as a motive power.

Exactly the same process is worked out in the case of the telegraph. The sender of the message despatches the electricity along the wire, the wire is traversed instantly throughout all its length, the electricity thus conducted to its destination sets special machines in motion, and, having accomplished its work, the electric current escapes into the earth. Different mechanical arrangements are thus

put in motion and corresponding signals are produced.

We might trust our comparison between the water-wheel and the telegraph still further. The water is conducted to the wheel by a canal, and in order that it may be able to turn the wheel it must come in sufficient quantity. If the water does not come in large enough volume, the wheel will not turn quickly enough, and the work will therefore be very imperfectly performed. If the volume of water is too great for the work to be done, a portion of it is lost, and of course a needless expenditure is thereby incurred. It is therefore important above all things to regulate the quantity of water by the force required to turn the wheel, taking into account all the circumstances that may interfere with the water having its full and legitimate effect. If there are any side canals drawing their supply from the main canal, calculation and provision must be made for the quantity of motive power thus diverted. The quantity of water lost by filtration must also be taken into consideration. The quantity of water must be regulated so nicely that it will supply all the necessary losses and yet be sufficient for its main purpose. If the amount wasted is invariable, then the delivery from the source should also be invariable and constant; if the losses are greater or less at different times, a corresponding increase or diminution in the quantity of water which is let into the main canal must be made. Thus, in setting up a water-wheel, one should consider carefully the quantity of water which the source is able to supply;

the losses incident to the nature of the canal it must traverse, and the character of the machinery it is intended to move.

When we wish to set up a telegraph we find ourselves compelled to submit to similar conditions. The electricity is produced in machines, technically called batteries. In order to make the electricity perform its work we must see that three conditions, similar to those we have referred to in speaking of the transmission of water as motive power, are complied with: First, the delivery from the battery, or the quantity of electricity produced, ought to be exactly enough, neither too much nor too little, to accomplish the purpose we have in view. Secondly, as this electricity produced in one place has to be conducted to another, we must provide for losses by the way. These losses consist in filtration or absorption by the air surrounding the telegraph wire. This absorption is always greater in proportion to the moisture of the air (for moisture is a conductor of electricity) and the length of the line. Allowances must also be made for losses through branches of trees which may accidentally touch the wire, and through the posts which sustain the wire. In the third place we must calculate the force necessary to set in motion the mechanism upon which the electricity is to act.

THE BATTERY.

Batteries have been constructed of all forms and all qualities since that of Volta, but many display

a very serious imperfection, viz., they at first generate electricity very abundantly, then the power of production diminishes, and after a short time stops entirely. The source is dried up, the battery is exhausted, and it is necessary to refit it anew. A machine of this kind is useful for certain purposes. For instance, it may be necessary to have a very large quantity of electricity in action during a short space of time, just as sometimes it may be necessary to accumulate a large quantity of water in the reservoirs in order to send it in a large volume upon a machine which had been stopped by an obstruction which the ordinary force of the water could not overcome. In telegraphy the conditions are different; the losses on the same line are tolerably uniform, and the machines to be set in motion are always the same. It is therefore necessary that the power of the battery be uniform and constant. The whole machinery will thus be always in working condition, without there being any necessity for losing precious time in collecting electricity. Whatever may be the qualities of a battery in other respects, it is necessary in telegraphy that its power be constant. It matters very little whether it produces a large quantity or not, for if one battery is insufficient for the work to be done, two batteries are united, and the number may be increased at will, until a power sufficient for our purpose be obtained.

Any battery, the strongest as well as the weakest, can put a telegraph in motion for at least a certain time. Each variety of battery has, however, some-

special quality which fits it specially for certain purposes; but only constant batteries are well suited for telegraphy. This application of electricity is the most important, because it is the most lucrative, and this accounts for the large number of inventors who have devoted themselves to the construction of telegraphic batteries.

The batteries used in French telegraphy will be described further on. It will be sufficient at present to explain, as we have done, the conditions with which the battery must comply. But though we have analyzed these conditions, although we have been able to account to ourselves for the surprisingly different properties of electricity, we must acknowledge that to this day electricity itself is a mysterious agent, of the actual nature of which we are ignorant. Is it a fluid, like water or air, or even like ether? Is it a peculiar kind of motion, or a particular state of the particles of the body?*

"Once," says an old Oriental story, "a sage dervis met a powerful fairy, who offered herself to him as a servant. The dervis, being a sage, accomplished many magnificent works through the power of the fairy. When the people asked who was this unknown and skillful laborer, the dervis replied, 'She is a fairy, and has not yet seen fit to reveal herself to me. But what does that matter?

* Certainly it is not a fluid of any kind, and just as certainly it is not matter of any kind. Science has at last settled these questions, and shown us that electricity is a state into which any kind of matter may be put; but she has not yet told us the exact nature of that state. Perhaps she will tell us, some day.—A.

I love her for all the benefits with which she has overwhelmed me.' Then the people, as they departed, wondered amongst themselves how the sage could perform such wonderful works through one unknown."

CHAPTER II.

MORSE'S TELEGRAPH—ELECTRO-MAGNETISM.

WHEN Volta invented his first pile, he was certainly very far from appreciating the full import of his invention. Before his time, electricity had been produced only in very small quantities, and in such an irregular manner that no great advantage could be derived from it. It was certainly possible to accumulate it in considerable quantities by means of large machines, but the electric fluid, as it was then called, disappeared entirely as soon as a way of escape was opened to it. A force which manifested itself intermittently and by shocks, could not be applied to any constant work; for such purposes it was absolutely necessary that the electric machine should develop a uniform and constant supply of electricity. The pile or battery invented by Volta it is true only allowed of the production of a comparatively feeble current of electricity; but this supply was constant and could be renewed, and for this reason the instrument became immediately one of the most important that had ever been invented.

In consequence of the arrangement which Volta

had adopted, his battery soon exhausted itself. At first it showed considerable power, but it very soon became unproductive. This defect being discovered, scientific men devoted themselves to the work of so modifying and improving the battery, as to render its supply constant and uniform. M. Becquerel, in the year 1829, was the first to solve the problem. Many natural philosophers disputed the honor of this important discovery, and each of them constituted himself the inventor of the first constant battery. But on a comparison of dates we think it must be admitted that Becquerel ought to be regarded as having preceded, if he did not inspire all the other inventors of similar batteries.

In every battery the electricity formed in the generator accumulates at two points, which resemble the feeding and discharging sluices of a reservoir. These points are called the *poles*. When we unite the two poles by a metallic wire, generally of copper, a continuous current is established, which moves with all the speed we have indicated. Whatever be the nature of the conducting wire, whatever its form or thickness, a current is always produced the moment the poles are connected. But if we cut this wire which conducts what is called the circuit—if we have a space between the poles, the current is interrupted, and it is only at the extremities of the cut wire that the electricity will then appear. From this it will be seen that it is essential that the two poles of a battery shall be united by conducting material before the battery can work.

In 1820, a Swedish savant, named Œrsted, having accidentally placed the wire of a battery in the vicinity of a compass, found that the magnetic needle was forcibly turned aside every time that the battery acted and the electric current traversed the wire. Ordinarily the compass points to the north; but Œrsted discovered that, submitted to the influence of the battery, the needle turned across the normal direction and indicated a line from east to west.

This fact having been demonstrated, one can easily imagine a system of telegraphy being built upon it. Say that a battery was established at Paris and its conducting wire led to Lyons, and there passed above a compass, and led back again to the battery at Paris. Each electric discharge from Paris—which would be as often as the operator connected the two poles of his battery—would cause the compass to deviate at Lyons; and all that would then be requisite would be to arrange the signals—that is, to arrange what intelligence was meant to be conveyed by one, two, three, or any number of deviations of the needle. This idea, due to Ampère, contains in it the germ of the whole system of telegraphy. But this system, possible in theory, was found very difficult to put into practice.

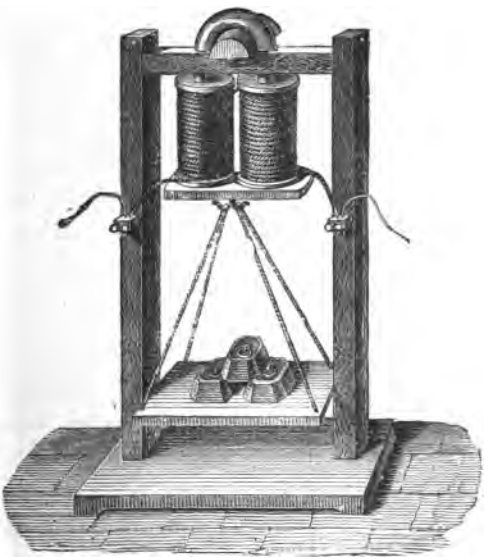
By repeating Œrsted's experiment, by studying under all its forms the influence of electricity upon a magnetic needle, it was soon found out that the current of a battery had the effect of strongly magnetizing a piece of iron. Thus, in coiling around this bit of metal a wire which unites the two poles of a

battery, while the current is passing, the iron is magnetized; but as soon as the current is interrupted by the wire being disconnected at one pole—the piece of iron returns to its natural state. It is necessary for the best results that the iron submitted to the experiment should be pure; cast-iron or steel, being more difficult to magnetize, always retaining the traces of magnetism. This fact, the result of the experiment of Œrsted, was immediately applied to practical purposes.

When a very strong magnet is found to be necessary, a large piece of iron, curved in the form of a letter U, is taken and wound round with a wire, the extremities of which are put in communication with the two poles of a battery. This wire is wound a great many times around each limb of the bent iron; each turn of the wire acts separately and magnetizes the iron in some little degree, until the action, increasing with every turn of the wire, becomes at last very strong. Such an instrument is called an electro-magnet. The attraction of a magnet is more powerful for soft iron than for any other substance. To ascertain the strength of a magnet, a bar of soft iron, long enough to connect the two ends of the magnet, and having a ring in its centre, is provided. This bar is called an armature. If this be placed upon the ends of the magnet, while the electric current is passing through the encircling wire, it will be instantly and powerfully attracted, and held with great force. Weights may now be suspended from the ring in the armature, and thus the force of the magnet may be measured. The force will depend

upon the size and purity of the bent bar and of the armature, the magnitude of the coil of wire and the power of the battery.*

But where only a single wire is used there is a limit, after which the number of turns of the wire have no influence on the magnetization—a limit



Electro-magnet loaded with Weights.

which depends upon the thickness of the wire, and on other circumstances which it would take too long to enumerate.†

* A bar two feet long and two inches in diameter may easily be made to sustain a ton.—A.

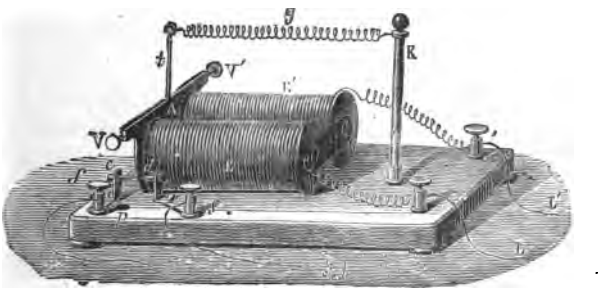
† Professor Henry and Dr. Ten Eyck, of the Albany Academy, discovered many years ago that 540 feet of wire, used as a contin-

This instantaneous magnetization of iron at a distance is applied in telegraphy. The important part of the receiving machine—the machine that records the messages sent from a distance—is a piece of iron similar to what we have described, called the electro-magnet, or magnet formed by electricity. It is shaped like a letter U, and surrounded with a coil of wire. It is marked E E′ in the illustration. In front of this piece of iron, and very near it, is suspended a little plate, A, of very pure iron and very light, which moves easily round the axis V V′; a restraining spring, *g*, offers a gentle opposition to this movement, and serves to bring back the plate to its normal position; this plate forms the armature. When the current passes around from the wire L to L′, the U is magnetized, and of course im-

nous coil, would cause a U magnet to sustain a weight of 145 lbs.; while the same wire cut into nine equal pieces, and each piece wound on a separate part of the magnet, and the projecting ends properly soldered to the copper and zinc cylinders of the single cell, would cause the same bar to sustain 750 lbs. In a subsequent experiment 20 pieces of wire, each 31 feet long, were wound on a bar, as in the first case, and the ends attached to a copper and zinc battery of five square feet surface. This electro-magnet supported 2,063 lbs. These experiments show a simple method by which the limit mentioned above may be evaded, and the same battery and iron bar be made to exert a vastly greater magnetic force with the same number of turns.

They show also how a vastly longer wire, and a vastly greater number of turns in the aggregate, can be used effectively with the same U bar and the same battery. We are not aware that any practical use is made of this principle, in either American or European telegraphy. Might it not be employed successfully to diminish the size of the batteries employed, and also the necessity for relays?—A.

mediately attracts the plate of iron, A, which consequently adheres to it. As soon as the current ceases and the U is no longer a magnet, the plate returns, under the action of the spring, to its first position. We can thus give to a plate of iron an oscillatory movement, more or less rapid, according to our wishes. Different mechanical contrivances make use of this movement. Thus, for instance, does the piston of a steam-engine act. It is pushed up by the steam, falls back into its former position, either by its weight or by the action of the steam, and an oscillatory motion is thus communicated to



Telegraphic Electro-magnet.

it, which in turn is communicated by a series of joints and cranks to the fly wheel and the rotating shaft.

A similar movement takes place in the electric machine which we have described, and somewhat similar are the different transformations of the elementary movements of the armature or plate which characterizes the different telegraphic systems. In the steam-engine this change from one motion to

another is very simple, and the machinery is arranged so as to produce it with certainty. But with the telegraph the question was more difficult. It was necessary to obtain in every part the utmost mobility and delicacy, and at the same time a motion large enough to be easily observed; it was necessary that the new organs should be as sensitive as the electro-magnet, and yet remain as firm and reliable. This result was not obtained at the first trial. Deep study and research were required, and even to-day, when the telegraph has attained a remarkable degree of perfection, there yet remain some details that call for improvement. Every day brings into notice new imperfections, and scientific men labor incessantly to remove them.

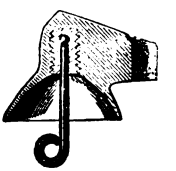
Of all the telegraphic systems yet employed or proposed, that of Morse is at once the simplest and the best. This American savant had invented and almost perfected his telegraph as early as 1831; but it was not until 1838 that he succeeded in getting companies to adopt it. After the latter year, however, all the telegraphic companies gradually adopted his system. In the Morse telegraph the armature or plate is furnished with a steel point or style, which makes marks, in the form of dots and dashes, upon a narrow strip of paper, which is made to roll out like an endless tape, by machinery. These dots and dashes, arranged in different combinations, form an alphabet which any boy in a telegraph office may soon learn to read.

AERIAL CIRCUIT.

An electric telegraph consists always of a conducting wire, forming the circuit of the battery, a manipulator for sending the dispatch, and a receiver, which registers the message sent at its destination.

The wire forming the circuit is arranged in the same manner in all the systems. It is a wire of galvanized iron suspended in the air, sunk into the soil, or plunged into the sea. For these last circuits it is necessary to take certain precautions, of which we will treat further on.

The aerial wire is sustained upon posts of wood, placed at a distance of about 160 feet one from the other. It is generally laid along the highways or the railways, in order that the surveillance of it may be constant and easy, and that any accident may be perceived and attended to without loss of time. The wire passes over hooks, suspended within bell-shaped cups of porcelain.



Insulator.

Every time that an object of whatever kind touches the wire, and puts it into electrical communication with the earth, that object gives a secondary or collateral passage to the electricity, forming, as it were, a sort of branch canal to the main wire. Consequently, there immediately results a loss of electric force, which weakens the principal current —a loss that is greater in proportion as the accidental conductor is more easily traversed by the electricity. At each post, at each tree branch,

which, swayed by the wind, comes in contact with the aerial wire, the current of the wire divides itself into two; the one continues its way along the circuit, and goes on to move the telegraphic machinery; the other is lost in the earth. These deviations are continually recurring, and weaken the chief current. It is therefore necessary to avoid the contact of exterior objects, or, when this is unavoidable, to diminish as far as possible their evil influence. For this reason porcelain or glass is employed to sustain the wire, and connect it with the posts, because it is a bad conductor of electricity. Just as an impenetrable bed of clay prevents a current of water from leaking through, so the porcelain and other insulating substances do not conduct away the electricity, but allow it to pass along the wire undiminished from the contact. But when the porcelain cups become wet, the moisture, being a good conductor, is easily traversable by the electricity. To obviate this inconvenience the cups are inverted, and arranged with the hollows downwards, so that rain cannot penetrate into the interior. The surface which is brought into contact with the iron hook is by this means kept almost dry. In order to establish an electric current it is necessary that the wire, after having gone round the electro-magnet of the receiving apparatus, should return upon itself to the second pole of the sending battery. This being the case, one would imagine that it was necessary to have two wires for each line; but it has been discovered that a single wire is sufficient. At Paris, for example, one of the poles of the battery is put

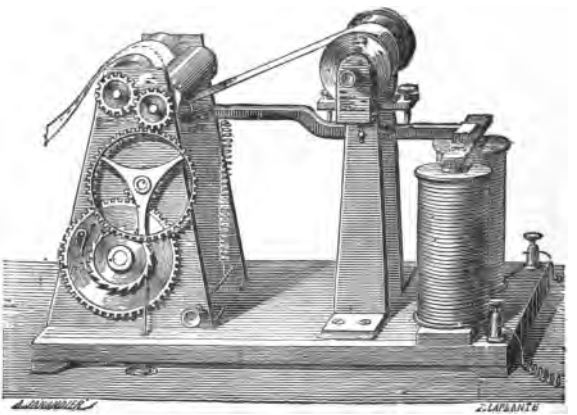
into communication with Lyons, and the other pole is united with large plates of metal sunk into the moist earth. At Lyons, the wire arriving from Paris traverses the receiver, and passes along the wire attached to plates sunk in the earth as at Paris. By this arrangement the earth serves as the second wire, and carries back the electricity to the second pole of the sending battery. The current thus returned is more perfect than if it had passed along a second wire. The earth, which is thus able to absorb immense quantities of electricity, and carry them unimpaired to the desired point, is called the common reservoir.

THE RECEIVER.

The receiver is the machine which receives and registers the message. It is composed of an electro-magnet, which imparts to a piece of iron an oscillating motion, which, by appropriate mechanism, is made to produce signals. We have already seen that the Morse machine itself prints the message upon a strip of paper, which unrolls gradually before it.

The electro-magnet is vertical and the armature horizontal. The latter is attached to one end of a nicely adjusted lever, resembling the beam of a balance. At the opposite extremity of this lever is fixed a style, which marks points or dashes upon the paper. When the current passes, the thin plate of iron constituting the armature, attracted towards

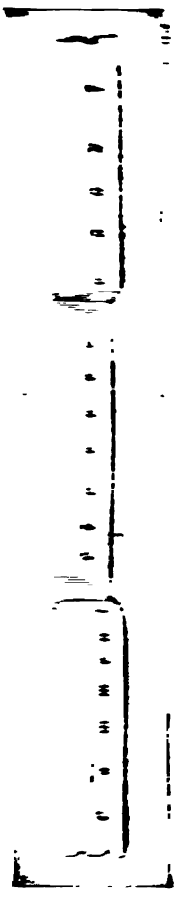
the electro-magnet, is depressed, and rests upon the magnet. The end of the lever which is attached to the plate of iron is of course brought down like the beam of a balance, inclining itself toward the weight. But the style at the opposite end of the lever (which moves on a fulcrum) is at the same instant raised, and pressing against the band of paper, drawn between it and a grooved roller, makes a mark upon



Receiving Apparatus.

it. As long as the current is passing, the machine remains fixed in this position, and the style is all the time making a long dash upon the unrolling band of paper, being made to move regularly by clockwork, altogether independent of the electricity. At the moment, however, when the current is interrupted, a spring draws down the lever, so that the style no longer touches the paper, but allows it to roll on without receiving any marks.

If the current be made to pass suddenly and then be suddenly interrupted, the style of the lever rises and falls as suddenly and marks a dot on the paper. If, on the contrary, we allow the current to flow for some little time, the style rises and marks a dash, which is traced as long as the passage of the electricity continues, and the paper will present a continuous embossed line. It is the succession of points and dashes that constitute the message.



Paper Band

A conventional alphabet has been adopted, in which each letter is represented by the combination of dots and dashes. It would have been easy to vary the length of the dashes, and thus to obtain a number of elementary signs, but this arrangement would have led to confusion, and it has been preferred to preserve only the simple point and dash, without reference to the length of the latter.

One alphabet is commonly used on all the telegraphs in Europe; it contains no secrets. Those letters of the alphabet which occur most frequently are represented by the simplest signs; thus *e* is

represented by one dot, *i*, by two dots, and *t* by a single dash.

A clerk who has had some little experience can read a message as it is unrolled from the receiving machine, without either requiring to refer to the alphabet, or to go back over the preceding parts of the band of paper. The letters are separated one from another by a space, and the words by a wider space.

The illustration represents a band of paper bearing the French words, "*Comment recevez-vous?*" (How are you receiving?) This question, frequently repeated in the telegraphic service, refers to the state of the wire, in order to know if the signs are distinctly received, and if communication is established. If no response be received, or if the answer be unfavorable, the despatch clerk takes it for granted that the current is interrupted, and waits till the connection is re-established.

Besides the signs belonging to the usual telegraphic alphabet, others which have a complete meaning in themselves, are made use of. Thus a series of dashes followed by a dot, intimates that a message is about to be sent; a series of dots followed by a dash intimates that the message is ended; a series of dots tells that the receiver does not understand, and so on. The commonest words—those which recur most frequently—are indicated by contractions.

Private messages, written in the ordinary language, are transmitted by means of the usual alphabet. But secret state despatches, messages of government officials, ambassadors' notes, etc., are written

in secret alphabet, the keys to which are possessed only by the parties interested. The intermediary stations receive and transmit them without understanding them, the address alone being in the ordinary language. In such cases an official of high rank, the chief of the telegraphic station, or his substitute, always receives the despatch. Whatever be the nature of the missive sent, the signs are transmitted; they are printed on the strip of paper, and lest there may be an error in the reading or the transmission, the strip is preserved and the despatch can be corrected.

It is necessary that the strip should unroll with a uniform degree of speed, because if it stopped for a few seconds, the style would continue marking at the same place and the message be unintelligible. As we have said, the strip is made to unroll regularly and incessantly by means of a separate arrangement of clockwork. There are two rollers which act upon each other and drag out the strip of paper between them. One of these serves as the point of support against which the style embosses its marks upon the paper. To render the marks all the more distinct, there is a narrow groove cut round this roller exactly opposite the style, which, striking the paper into the groove, makes a more distinct impression. This clock movement can be arrested or liberated by a very simple contrivance, and when the clerk receives intimation that a message is about to be transmitted, he liberates the machine weight and leaves it free to act. The clockwork then goes on, and the paper strip, upon which the style is now

busy printing, comes away regularly and continuously. As soon as the message has been transmitted, the clockwork is again stopped, and the paper is not needlessly unrolled. The band of paper is rolled upon bobbins which complete the furnishing of the receiver.

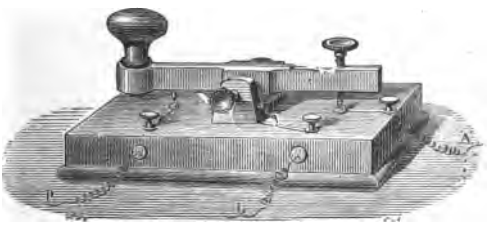
THE MANIPULATOR.

The manipulator is the machine by which the message is transmitted. Its function is to turn the electricity into the wire, or to interrupt the current, according to the will of the operator; in other words to connect or disconnect the poles of the battery. Its construction is determined by the nature of the receiver.

The manipulator used in Morse's system is of extraordinary simplicity. One of the poles of the battery communicates with the earth, and another with a copper button placed upon the manipulator. A screw insures contact between the wire and the copper button, and can render the wire of the battery, P, completely independent. By means of this button electricity enters into the machine. A metallic plate runs from the button and ends in a point. There it stops, and in the ordinary state of metallic communication, the electricity accumulates at the point which becomes one of the poles of the battery.

Above the point is a copper lever, which, in its normal state, does not come into contact with it, being kept raised above it by a spring; but it is in *constant communication* with the telegraph line by a

wire, L, which traverses the axis upon which it turns. When the operator presses upon the knob which terminates the lever, he lowers it and makes it touch the point at the pole of the copper plate, at which the electricity is accumulated. By this act the circuit is completed, the lines Z and L are brought into connection, and immediately the current passes and enters the line. The instant the clerk ceases to press the lever it rises by the action of the spring, and the current is interrupted. This lever constitutes the entire manipulator, and is called the key. Consequently, all that is necessary



Morse's Manipulator.

is to act upon the key, to lower or let it rise, in order to make the current pass into the line or to arrest it. If it be lowered during a greater or less length of time, the current fills the line during that time; thus are met all the conditions demanded by the receiver.

Each telegraphic station possesses a receiver and a manipulator. The wire, for example, that carries messages from Paris to Lyons brings also return messages from Lyons to Paris. For this purpose it has been necessary to add to the manipulator certain pieces, which permit of the establishment of

a continuous passage from the line into the receiver. In order to effect this, the key is made to rest, at the extremity opposite the hand, upon a second point, which communicates by the wire, A, with the receiving machine.

So long as the lever is in repose, that is, so long as it is not pressed down at the knob, the telegraphic line and the receiver are in communication by means of the point at the extremity of the lever, and the wire, A, consequently the machine is always in a fit state to receive messages. If the clerk wishes to speak, and make use of the manipulator, the key, on being pressed, raises the point from the button of the receiver. The two mechanical arrangements are completely independent of each other, and both are always ready for action. It is needless to add that a station only answers when the corresponding station has ceased to speak; otherwise the messages would cross on the line, and nothing would be communicated.

One can hardly imagine all the difficulties which young persons experience in endeavoring to acquire the habit of transmitting a despatch successfully. Great regularity of movement is necessary in order to secure distinctness of signals at the other end of the line. The dashes should be as nearly as possible of uniform length, and the points or dots should be distinctly marked. The intervals between the letters should be equal, as well as the longer intervals that occur between the words and sentences. Under such circumstances only will the dispatch be easy to decipher.

The advice given to young telegraphists, desirous of excelling in transmitting messages, are similar to those given to musicians to improve their "time." A guide upon the subject has been published in Switzerland, which those who wish to attain, as soon as possible a high degree of facility in sending messages generally follow. This method, sometimes followed also by musicians, is as successful as it is simple. It consists in measuring each beat of the knob of the transmitting key by the syllables *di* and *doo*: the one for the dots, the other for the dashes. This guide contains, also, elaborate instructions as to how to pronounce these syllables with regularity. In striking with the finger upon a table, so that the blow shall exactly correspond with the syllable pronounced, the operator will succeed, says the guide, in learning to make the registered telegraphic signals without using the telegraphic machine. The lever or key actually makes a sound resembling that of the syllables when articulated, which greatly assists the young telegrapher in his labor. This also is the case with the receiver, the armature or plate of the electro-magnet making a sound resembling the *di* or *doo*, according to the length of time it is in contact with the magnet. Thus, experienced persons can, by simply listening to the machine, tell the sense of the whole dispatch. Those who are less experienced can comprehend the dispatch by following with the eyes the movements of the armature. This practice is recommended to young telegraphers as the best discipline for perfecting them in their profession.

CHAPTER III.

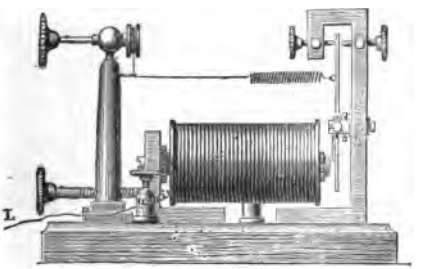
DIFFERENT INSTRUMENTS EMPLOYED IN TELEGRAPHY.

BESIDES the receiver and the manipulator, which constitute the principal and indispensable machines employed in telegraphy, there are other instruments which are very important, and without which telegraphs would not work. Different instruments, necessary and accessory, and common to all the systems, have been successively adopted to provide against the inconveniences which practice was daily making known. These instruments are the result of investigations made independently, by different scientific men, and have contributed greatly towards ease and regularity in the practical working of telegraphic lines.

RELAYS.

The losses to which an electric current is exposed in its course along the wire are generally small and uniform; but incidentally they may be suddenly increased. It rains, for example, and the moist air carries away great quantities of electricity; the

posts supporting the wires are by the moisture made better conductors, and the waste consequently becomes considerable. Often, also, the branches of trees happen to touch the wire, and an unforeseen breakage takes place, which considerably weakens the electric current. It may therefore happen that the electricity sent by the manipulator does not arrive in sufficient force at its destination, and cannot accomplish the work demanded of it, and set the machinery of the distant receiver in motion.

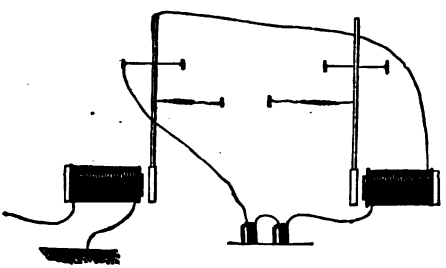


Froment's Relay.

In order to prepare for, and provide against, these contingencies, electric relays have been constructed at certain regular stages. As when a vehicle requires to travel a great distance, fresh relays of horses are taken on at different stages, and the travelling power is thus kept up; so, when the current of electricity has become much enfeebled by accidental losses or by absorption in its progress along the wire, it can be reinvigorated at certain stages by electric relays. The object of these relays, it will thus be seen, is to take the place of the ex-

hausted current coming along the line, and to substitute for it a stronger current, furnished by a local battery. This local battery should always be sufficiently powerful to set the signal apparatus in operation.

The wire of the line communicates with the electro-magnet of the relay, the light armature of which is the more easily moved, in that it has no apparatus to set in motion. This armature communicates constantly *with one of the poles* of the



Theory of the Relay.

local battery. In repose, when the armature is not attracted to, and therefore not in contact with the electro-magnet, the circuit is interrupted; but as soon as the electricity of the line, however feeble it may be, penetrates the electro-magnet of the relay, the armature is moved and touches a metallic point in front of it. This point is in connection with *the other pole* of the *local battery*, and the armature, which is in connection with the first pole, thus completes the circuit. In this local current is placed the receiver; as often as the electricity of the line

displaces the armature of the relay, so often the local battery acts with its new force upon the signalling apparatus at the distant station. Thus a current, the power of which is doubtful, is replaced by another as strong as it is necessary, without the signals being affected. The relays, which, so to speak, give to the local electricity the commission to act, can render great services. They are all the more useful, in that the local batteries are necessary for the ordinary business of the station.

When Morse came to England, his system was unanimously repudiated. The English were already in possession of another telegraph, invented by Wheatstone, more complicated, but more perfect than Morse's. The latter required an immense electric force, and could act at only short distances. Consequently the American apparatus, so admirably simple now, was then abandoned until the inventor had taken advantage of the English system of relays. Morse at once appreciated the new idea, and applying it to his apparatus, enabled it to act at all distances.

Since that time relays have been much simplified, and at present they are adapted to almost all machines.

TRANSLATORS AND TRANSMITTERS.

Often a station is traversed by a despatch without receiving it, either because the station is unimportant, or because the despatch is a secret one

state rests against a piece of metal. The current from the battery passes to the armature from this piece of metal, and from the armature into the electro-magnet, which rings the bell. As soon as the electricity arrives, the hammer, attracted by the magnetized iron, strikes upon the bell. In performing this movement, it leaves the piece of metal, and the current being interrupted, the hammer, no longer attracted, falls back and resumes its position. The current is thus re-established, and the process is repeated. There is produced in this way a series of attractions, and of rapid strokes of the hammer, forming a kind of shrill, tremulous sound, which continues until the person superintending the receiver is called to his duty, and checks the circuit.

Whenever the telegraphist has to leave his machine, he places the line in connection with his alarm bell. By means of this precaution, he is called as soon as the preliminary signals of a despatch are made. He at once answers that he is ready, and arranging his apparatus, receives the despatch.

THE LIGHTNING-ROD

The lightning, which makes known its presence in the flash and the thunder-peal, and of which the effects are so terrible, is nothing else than an electric discharge. Thunder clouds highly electrified pass through the air, carrying destruction in their train. The machines with which men of science

amused themselves, prior to the invention of the battery, produce the same effects as the lightning. But the electricity thus developed is not of the same nature as that which comes from a battery. Each has different properties, and acts in a different way. Lightning melts and consumes the metallic wires along which it travels. Thus when lightning strikes a house, it melts the bell wires, the mercury of the looking-glasses, and all the metals which it encounters in its track. It shows, however, a remarkable tendency to pass into pointed conductors, and to be dissipated from them, and it was the observation of these phenomena that led to the construction of lightning-rods. Electricity produced from a battery, on the contrary, possesses these properties of the lightning in a very feeble degree. From a small battery it hardly heats the wires along which it travels, even when these are very fine; it passes by objects that are pointed as freely as others, and is not dissipated while passing along pointed conductors. It is therefore capable of being transmitted to great distances without sensible loss from the action of points. This last property has been ingeniously taken advantage of in telegraphy. Different names are given to electricity existing under these two conditions; although these names unfortunately convey only very imperfectly the meaning they are intended to bear. The electricity from the battery is called *dynamic*, while the other is called *statical*. These terms have merely a technical signification.

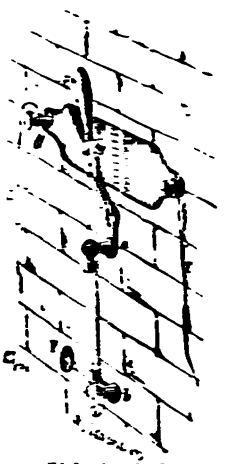
During a thunder-storm the atmosphere is charged

with electricity, and the current which traverses the telegraphic wires is considerably modified. It draws along with it a considerable quantity of atmospheric electricity, which courses along the wire from station to station. At other times the lightning, in exploding in the air, strikes the telegraphic wire and follows it out to the end as it does the chain of a lightning-rod.

Arrived at the station this atmospheric electricity may occasion the gravest accidents. The wire coils of the electro-magnets may be melted, the machinery destroyed, and the clerk killed. These accidents are all the more dangerous when the thunder-storm which produces them takes place at a distance and cannot consequently be provided against. Very frequently the public journals have to record effects as extraordinary as they are fatal, produced by these unexpected explosions. People are knocked down, articles displaced, whole rooms in fact turned upside down, and a confusion caused which would be comical if it was not so dangerous. It is therefore of the greatest importance to protect those edifices against the lightning, even though the means employed for this purpose should render the transaction of ordinary business impossible. Accordingly, where a thunder-storm of any violence is signalled as approaching any line, all the wires of that line are connected with the earth, and thus all the electricity, of whatever kind it be, brought by these wires, is let off into the ground without being allowed to pass into the instruments. Should it be found necessary to send any messages at such a time, it is done by a

circuitous route. A line is chosen that is not in the track of the thunder-storm, and by this line the message is made to reach its destination.

When the storm is not very violent, it is found sufficient to place a lightning-rod in the current by way of precaution. This instrument allows only the electricity of the battery to pass, and entirely separates the lightning that accompanies it. With the same object, all communication between the line and the telegraphic machines can be interrupted, and the wires led to the earth.



Lightning Rod.

Lightning conductors employed in connexion with railways, are very simple in arrangement; and as they will assist the reader in understanding the principle upon which more complicated instruments are constructed, a few words of description may be given regarding them. The wire coming from the line communicates directly with a plate of metal furnished with many points, which make it look like a sort of comb. Opposite this plate is another of the same shape, and communicating electrically with the earth. The lightning, following the line of the wire, is drawn into the first of these plates, passes from its points to those of the opposite plate, and escapes by this into the earth; but dynamic electricity from the battery cannot leap the space between the points and continues

its route, passing into a very fine copper wire enclosed in a glass tube, and is thus carried into the receiving instrument. If the lightning came in too great quantity to escape entirely by the points, it would be conducted along this very fine copper wire, which would be immediately melted. The passage would then be intercepted and no more electricity would be allowed to pass into the receiving instrument.

The electric force capable of passing this fine wire before melting it, is too small to either injure the instrument or endanger the operator.

As soon as the transmission becomes irregular, or the signals confused, it is presumed that there is a thunder-storm on the line, and the lightning-rod is immediately put in operation. If this precaution is sufficient, the work of transmission may be continued, if great prudence be observed; but if the fine copper wire should melt, the line wire must be immediately connected with the earth. The lightning conductor is in fact far from being as efficacious as might at first sight appear, and it is necessary not to repose too much confidence in the protection it affords; for one ought to feel above all things that lightning is terrible.*

Owing to the minute precautions observed at telegraphic stations, it seldom happens that, when they are struck by lightning, much havoc results. On

* Though its action is governed by well known laws, some of the surrounding conditions are liable to great and sudden changes which it is impossible to foresee or control. For this reason, its effects can never be minutely predicted or certainly guarded against.—A.

the line, on the other hand, the thunder-storm frequently bursts directly over the wires; many posts are then struck, traversed, and rent from top to bottom, and yet often without disabling them in their work of supporting the wires.

COMPASSES AND GALVANOMETERS.

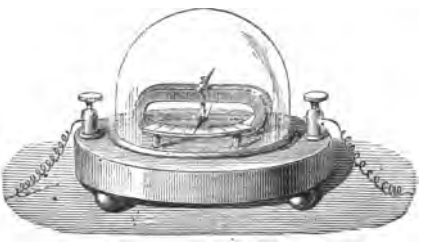
Œrsted's experiment, which was the basis of electro-magnetism, and in consequence of the telegraph, shows the influence of a current upon a magnetized needle. It also serves to show if a metallic wire is traversed by a current. The action of the wire upon a compass placed beside it, will determine this immediately.

Upon this principle, an instrument named a galvanometer, indispensable to all researches in electricity, has been constructed. So wonderful is the sensitiveness of this instrument that it detects the presence of the weakest currents. This quality renders it extremely valuable in the telegraphic service, as well as for the highest scientific investigations.

A very delicate magnetic needle, suspended by a single filament of silk, is placed over a horizontal graduated circle. In order to increase the mobility and to counteract the action of the earth as far as possible, there is joined to this needle a second one as like the first as possible, in form and degree of magnetization.*

* These needles are arranged so as to hang one exactly above the other, parallel to it, and with its poles in the opposite direc-

Of the two needles the one is visible upon the circle and traverses its divisions, the other, placed underneath, is surrounded by a frame of wood, open at opposite sides. Around this frame, as upon a bob-



Ordinary Compass.

bin, are wound many coils of a copper wire, covered with silk, so that each turn of the wire is isolated from the neighboring turns.*

tions. To secure this relative position, the two needles are firmly attached by their centres to a brass rod ½ or ¾ of an inch in length. They are thus suspended, so as to rotate freely in a horizontal plane. As the like poles point in opposite directions, the magnetic forces of the needles balance each other, and they will have no tendency to turn away from any point of the horizon to which they may be directed. Such a combination is called an Astatic Needle. As it is not interfered with by the magnetism of the earth, it is sensitive to the slightest magnetic influence properly brought to bear upon it. To render it perfectly astatic, it is necessary not only that the needles be magnetized to exactly equal degrees, but also that the magnetic axis of the one lie exactly above the magnetic axis of the other. The first condition can be met without serious difficulty, but the second condition, and apparently the easier, it has never been found possible exactly to satisfy.—A.

* These turns must be parallel to one another, and formed by passing the wire alternately above and below the needle, over the closed ends of the frame.—A.

It is by means of this wire that search has to be made to detect the current. For this purpose each extremity of it is connected with a copper button to which the wire to be experimented upon is attached.

As in the electro-magnet, each turn acts separately and deflects the needles. However feeble the current may be, its action, multiplied by the number of the turns of the wire, becomes perceptible; and as this action plays upon each needle, tending to move them both in the same direction, it will be seen that the sensitiveness of the instrument is without limit. In ordinary experiments the investigator is content with from 25 to 30 turns of wire around the frame; but for delicate observations, demanding great exactness, instruments are made use of, having generally 150 turns and in some cases as many as 17,000, which represents a length of several miles.

The stronger the current which is manifested by the galvanometer, the greater is the deflection of the needles, and it is therefore possible that the power of the current may be measured by the amount of the deflection. The circle upon which the needle moves is graduated, and the degree to which the needle is deflected indicates the strength of the current. The galvanometer becomes as it were a compass, which by a simple reading and a few easy manipulations, gives the measure of electric currents. In telegraphic stations, instruments are employed, differing a little in form, but the same in principle as the ordinary galvanometers.

All stations should be furnished with compasses and galvanometers. Generally one of these instru-

ments is fixed, fitted into a table, and covered with a glass case, and it is consulted when the operator wants to know the state of the line. The deviation produced by a proper strength of current for receiving, is known beforehand. If the deviation obtained at any time is very feeble, then it is known that losses are taking place along the line; if, on the other hand, the deviation is sufficient, and the reception not good, it is concluded that some derangement has taken place between the galvanometer and the signalling machine.

Besides this fixed galvanometer, each station is furnished with other instruments of the same kind, movable and suitable for making experiments in different localities. It is necessary to have duplicates of all the instruments, for the chief difficulty of telegraphy arises often from the extreme sensitiveness necessary in the instruments. The smallest accident deranges them and makes them unfit for use, and hence the necessity for having a number of instruments, so that when one is disarranged it may be immediately replaced by another, known to be in proper condition.

BATTERIES.

The choosing of the battery is of the first importance in telegraphy. An exact knowledge of the conditions which a good battery must fulfill, and the many qualities which it should combine, is requisite in order to be able to make a selection from

among the numerous instruments offered and highly recommended. As we have already stated, the principal condition is that of constancy and uniformity of delivery. It is absolutely necessary that the machine should produce nearly the same quantity of electricity within a given time, without becoming soon exhausted. Then the battery should be easy to work, so that the under-operators, even those whose reputation for carefulness is not great, may be able to put it in action, to repair, and to clean it. These are the conditions of excellence which a company must naturally look for. Further, as one cell can only produce a limited amount of electricity, and is not sufficient for the work of a whole line, it is necessary to join several cells together, in order to increase the power and render it competent for the work. But this combining of cells, if it increases the delivery, renders the manipulation more and more difficult, and this inconvenience soon increases beyond measure. It is necessary, therefore, that each cell should of itself produce as much electricity as possible, that only a small number of them may need to be combined.

Each of these cells furnishing its contingent of electricity is called an element, and the aggregate of the elements whence flows the definitive current is usually called the *battery*.

To these first conditions, which are simple and evident, ought to be added some others, which experience has shown to be necessary, and which result, probably, from some of the less known properties of electricity. As these latter are at the present

time difficult to explain, they are the most frequently overlooked by those who are not exact in scientific examination. Moreover, when, after several careful trials, a new battery is rejected, the inventors complain that they are sacrificed; and this too with some degree of justice, seeing that satisfactory reasons cannot always be given why their battery has not been accepted. We shall attempt—not to explain—but to render comprehensible these important conditions which we class under the common name of interior resistance.

When electricity develops itself in an *element* of the battery, it springs into being, so to speak, at every point, and these numerous atomic centres of electricity, in their turn, move gradually in the anterior of the element and concentrate their force at the two poles. There are two poles, because there are two sorts of electric force, each of which possesses some special character, and shows itself at a special point. From the union of the two poles, and the action of the two accumulated electricities, the current is formed. When a number of elements are to be united, care must be taken to insure that all the separate currents of electricity formed in each of them be conducted to two single poles, and for this purpose it is necessary that the means of union should be easy, and that there should be no considerable loss by the way. This last fact is expressed by saying that the interior resistance of the pile should be very feeble.

For a long time it was believed that this cause of loss, which in certain arrangements becomes enor-

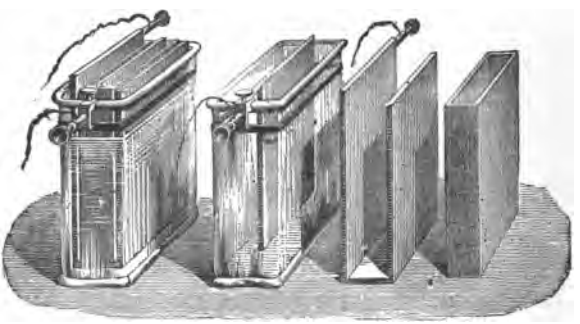
mous, might be overlooked. It was believed that the circuit, if long and very resistant, occasioned losses so great that, in view of them, the interior losses were very small. But one fact was discovered that could not be explained. It was found out that the interior resistance of a battery increased considerably in comparison with the losses produced in the circuit, so that in this case, not only the principal current was weakened at the extremity, but the strength of the battery itself, also, was much diminished. The current, in short, had no longer sufficient force to reach the receiver.

In consequence of the necessity of fulfilling these difficult conditions, the varieties of batteries employed in telegraphy is very limited. In America, Bunsen's battery is still in use, of which mention will be made further on. In France, the only batteries employed are those of Daniell and M. Marie Davy—all the others having been rejected.

Daniell's battery, which down to the present time is the most commonly employed in Europe, consists of a series of elements, arranged in the following manner: A vase of plate glass is filled with water mixed with sulphuric acid, the mixture being formed with one part of sulphuric acid and ten parts of water. Into this acidulated water is introduced a plate of zinc, bent so as to form three sides of a narrow box. The vitriol instantly corrodes the metal, and burns it up, until it is gradually dissolved. To this chemical action is due the production of the large quantities of electricity evolved. In order to avoid a too rapid corrosion of

the zinc, and especially a needless corrosion when the battery is not being used, the metal is amalgamated, or covered with a coating of mercury. This simple expedient lessens the destructive action of the acid without involving serious inconveniences.

The amalgamated plate of zinc, attacked by the acid, is charged with electricity, and becomes one of the poles of the battery, called, therefore, the zinc pole. In the acidulated liquid is also placed a very porous vase of earthen ware, full of a strong



Daniell's Battery, disconnected and in action.

solution of blue vitriol, or sulphate of copper. The porous vase has the property of separating the liquids, and not permitting them to mingle for a very long time, without, however, arresting the passage of the gas or electricity. Finally into this vase is plunged a plate of copper, which will form the second pole of the battery. The electricity, opposite in kind from that which is formed upon the zinc, traverses the first liquid, the porous vase, then

the second liquid, and is accumulated upon the plate of copper which forms the second pole.*

Such is the construction and operation of Daniell's cell. The form and dimensions of the plates were resolved upon only after frequent experiments, aided by mathematical calculations which should not be neglected, although the difficulties which it entails upon students of telegraphy do not at first appear to be followed by corresponding results. But this opinion is soon modified.

The porous vase of this apparatus gave the greatest trouble. From this comes the greatest *interior resistance*. It has undergone many improvements, and after much care and study spent upon it, investigators have agreed to adopt the form of a narrow, rectangular box. In the interior is a grating, invisible in our illustration, and filled with crystals of blue vitriol, which supply the liquid as it becomes exhausted.

This battery has the advantage of being at once strong, constant, cheap, and very easily manipulated. Its interior resistance is certainly great, but this defect decreases in time; for the porous vase becomes at length incrusted with crystals that facilitate the passage of the electricity. Another

* The hydrogen gas disengaged by the oxidation of the zinc, no longer appears upon the surface of the zinc as a coating of small bubbles, protecting it from the action of the acid, and greatly diminishing its power of producing electricity; but, after several interchanges, it unites with the oxygen liberated from the blue vitriol so quietly, that there is no effervescence of any kind in the cell.—A.

inconvenience consists in this: that the metallic portions, outside the liquids also, become coated with crystals of sulphate of copper. This causes loss of electricity. Many experiments have been tried to prevent this; the most simple being to remove every day the crystals thus formed. This plan has the good effect of causing the battery to be visited regularly.

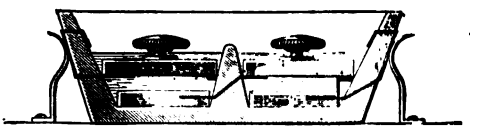
The second battery used in France, is the invention of M. Marie Davy. Doubt has long prevailed respecting the most convenient and effective arrangement which should be given to this new generator of electricity. The model at first preferred was a vase of glass or earthenware, divided ordinarily into two compartments, as shown in the illustration. At the bottom of each of the compartments was laid a plate or layer of carbon, covered with a paste made by mixing sulphate of mercury with water. A plate of amalgamated zinc for each compartment, furnished with a handle, rested on two metallic supports, and was wholly immersed in acidulated water. This arrangement rendered the employment of the porous vase unnecessary.

The two compartments were identical, and each of them formed a distinct *element*. The carbon of the one was in connection with the zinc of the other, and we have thus a complete battery, which could be made use of either alone or in connection with other similar batteries.

But it was soon discovered that this arrangement could not be depended upon for regularity of action, and it was found necessary to return to the

common model used in all batteries. As in the apparatus of Daniell and the other inventors, a vase of glass is now used enclosing a plate of zinc placed in acidulated water, and a porous vase is filled with sulphate of mercury, and a plate of carbon placed in the middle of it.

Here we find again the analogous elements to those in Daniell's battery. The carbon takes the place of the copper and transmits the electricity more freely without becoming covered with those crystals which cause so much loss. This is the result of the blue vitriol. The sulphate of mercury however, in the improved Marie Davy, replaces the



Davy's Battery.

blue vitriol, and as it does not dissolve in water, it admits of no mixture of the liquids. The plate of zinc is surrounded similarly with acidulated water, and the mercury, reduced by chemical action, actually keeps the zinc amalgamated during the action of the battery.

Here again the power is constant, and it is more considerable than in the preceding battery, the resistance being less and the manipulation more easy. But the sulphate of mercury is very poisonous, as are also the salts of mercury, and the employment of this material is very dangerous. Moreover, this substance is excessively dear, but these incon-

veniences are compensated by the advantages which the battery possesses.

Thirty-eight of M. Marie Davy's elements act night and day, supplying a line of three hundred miles in length, with a force which is kept up for three months, twenty-seven days; while Daniell's battery, to do the same work, would require sixty elements, and the power would not remain constant more than two months, twenty-five days. These figures will serve to show for what reasons the use of the sulphate of mercury battery tends to become more and more general. At first employed as a local battery, it came afterwards to be used as a line battery, and if its use is still confined to central and some other important stations, it is because companies fear to place in awkward and unskilled hands so fatal a poison as sulphate of mercury.

This substance is now in ordinary trade at about seventy-five cents per pound, and although companies furnish themselves with it by contract, its price is still very high. It is right to add that each element consumes about three-quarters of an ounce of this substance per month, that the plate of zinc lasts three months, and that the battery requires no other attention than the addition of a little water from time to time.

The sulphate of mercury is sold as a very heavy white powder, which is steeped in water. This mixture is left to settle, when there appears at the bottom of the liquid a yellowish powder, which is collected for the purpose of being introduced into the battery above the carbon. The water which has

served to dilute the sulphate and [illegible] ration is acidulated is made [illegible] tery around the plate of zinc. [illegible] battery will, after a few days, be [illegible]

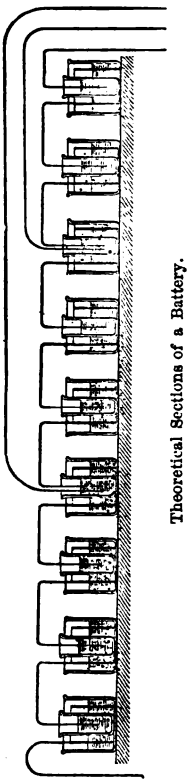
The battery of Leclanche [illegible] ant advantages, and is gradually [illegible] It consists of a plate of [illegible] roxide of manganese in the [illegible] saturated solution of sal ammoniac [illegible] The advantages are that [illegible] durable; the cost extremely small and the [illegible] supervision great. The only [illegible] feebleness of its action, requiring a [illegible] elements.

Whatever be the battery employed, it is necessary to combine several *elements*. The zinc pole of the first is connected with the earth while the copper pole communicates with the zinc pole of the second. The copper pole of the latter communicates with the zinc pole of the third and so on to the last *element*, the copper pole of which is put in connection with the sending instrument and the line.

The various elements of the battery must be kept separate, and ought never to be allowed to touch each other. They are commonly placed upon wooden gratings, in a dry, well aired place, in which is maintained a medium temperature.* Every day a skilled official visits the battery, examines the elements one after the other, adds what may be

* It has been found by different telegraphists in America that a certain amount of dampness, such as is found in many cellars, very perceptibly increases the energy of the batteries.—A.

wanting, and removes what may be superfluous. Thus attended, the battery lasts several months. After a certain period elapses, it is thoroughly cleaned and refitted; the metals are scoured, the vases cleaned, the liquid changed, and the zinc amalgamated—operations which demand the very greatest care.



Theoretical Sections of a Battery.

Under normal conditions, and with the apparatus employed in France, it is estimated that a battery of 30 of Daniell's elements is registered for a line of 65 miles; one of 50 elements, for a line of 130 miles; and one of 70, for 260 miles. The same current is sent to long distances as seldom as possible.

It is useful to be able at pleasure to separate from the entire battery a certain number of elements, in order that only the force necessary for the distance may be employed. For this purpose there are attached to the copper pole of the 10th, 20th, or 30th element, supplementary wires, independent of one another, and of the wires connecting the elements between them. These wires terminate in the manipulator, and the clerk can, as occasion requires, make use of one or another. In the subjoined cuts two supplementary wires are de-

picted, as attached to the fourth and the seventh elements.

In this way batteries are managed in France. In other countries the rules and conditions may, in some particulars, differ, but the principles are the same; and we can always, with a little attentive study, comprehend the various systems.

CHAPTER IV.

RAILWAY TELEGRAPHS.—PRELIMINARY CONSIDERATIONS.

THE electric telegraph is an important auxiliary of railways. From one station to another it is often desirable to signal trains, to communicate information, or to demand help. All these transmissions must be instantaneous or the most serious accidents may occur. Without telegraphs, railways could have been carried on only with difficulty, and even their continued existence might have been rendered precarious. It is not enough to regulate the hours for the trains, and provide for the details of the service. An involuntary imprudence, a sudden delay, an unforeseen accident on the road, a great number of circumstances, which no one could provide for, would have continually interfered with the best regulated system, and there would not have been any means of preventing frequent collisions, except by tedious and irritating delays. Accidents frequently occur far from all help, where the oversight of the railway is imperfect; and it is in such cases that the telegraph can signal the danger, and be the means of averting the greatest disasters.

The immense impulse which was given to railways in 1838 greatly favored not only the adoption, but even the invention of the electric telegraph. Various experiments and attempts were from time to time made to establish a system of telegraphy for the use of railways. But of all systems proposed, none succeeded.

A German savant, whose name is connected with all the discoveries of the telegraph, (Herr Steinhell,) established at Munich, in 1837, a telegraph upon a length of line of about three miles; and his attempt, though only half successful, caused those who witnessed it to be astonished. In America, Morse forsook painting, his favorite occupation, to devote himself to the study of the telegraph; and his system was publicly exhibited and explained on many occasions. These, however, were only crude attempts, which did not attract much public attention, although the number of them indicated that the question was being seriously studied, and that the moment of success was at hand.

It was upon the London and Birmingham railway that Mr. Wheatstone established the first electric telegraph, in 1838. After many interesting experiments in electricity, that ingenious man of science invented a particular telegraph, which has only been employed to a limited extent in consequence of the complicated nature of its mechanism. At the commencement this system, which was continually being improved by the inventor, worked for a certain time. This success clearly demonstrated that the electric telegraph was quite practicable, and

all that remained to be done was to perfect the apparatus. Men of science everywhere addressed themselves vigorously to the accomplishment of this task. England, Germany, and America had each its peculiar system. France, on the other hand, already provided with its system of aerial telegraphy, followed at a later date the movement that had been begun by the other nations.

In 1844, the first telegraph was established in France, for the special service of the line from Paris to Rouen. Upon trial it was found to answer every hope; its success was considered complete; and since that time every railway that has been constructed has been provided with telegraphic wires. The lines established after this early attempt were those from Paris to Orleans in 1847, and from Paris to Lille in 1848. At present the wires not only run along the railway, but also along a great number of the highways.

In order to combine as near as possible the electric and aerial telegraphs, a signal telegraph was constructed, the black arms of which were movable, and could take different positions. The alphabet was rendered uniform for the two systems, and during a certain time this telegraph alone was in use at the French telegraphic stations. After a time, however, the superiority of Morse's system becoming known, it was universally adopted, and superseded the old signalling apparatus. In the course of years the railway companies rejected all these different systems, and made use of an instrument almost as simple as that of Morse, but much

more easy to work and to understand, namely, the Dial Telegraph.

Simplicity of machinery, and facility in its use, are indispensable conditions in railway telegraphs. It is often important that any employee, a stranger even, should be able to work the telegraph. The proper person being absent, and a pressing signal being given, it is desirable that any one, however ignorant of the service of the railway or the telegraph, should be able to receive and understand the message. In asserting this we do not, of course, refer to secret and personal messages, but to facts which everybody has an interest in knowing without delay. This consideration had the effect of causing the dial telegraph to be universally adopted in France.*

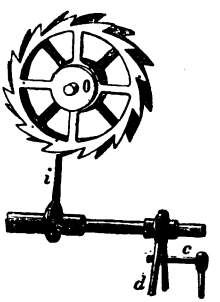
RECEIVER OF THE DIAL TELEGRAPH.

The receiver in the French dial system consists of a dial, with twenty-six divisions, which divisions are inscribed with the letters of the alphabet and a final sign. A needle moves round these divisions, stopping at the letters that make up the words of the message. When the needle has indicated all the letters in a word, it touches the final sign, so that it is only necessary for a spectator to watch the needle

* In America, such a telegraph could never obtain favor. Business men, and indeed all others, demand that their correspondence shall be kept private. Rather than not secure privacy they are willing to pay much more than may be necessary to provide for the constant attendance of properly instructed clerks at all the offices. — A.

spelling out the words, to learn the whole import of the message.

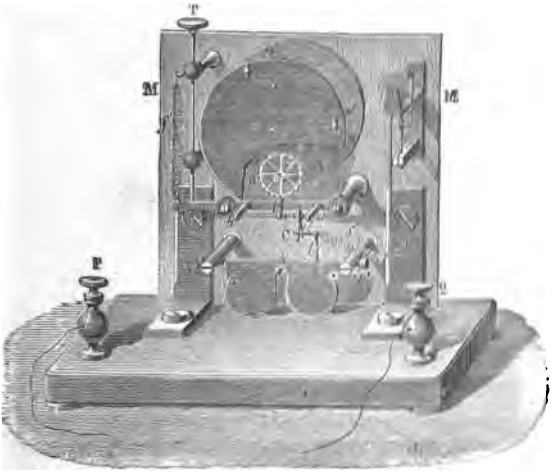
In this case, as in others, the electro-magnet regulates the deflections of the needle. The illustration on the following page represents the interior of the receiver, but in it the magnet is left out, as it conceals certain pieces of the machine. The armature is formed of a double plate indicated by the letter *A* in the figure; it works with an oscillatory movement, resulting from the alternate actions of the electro-magnet and the opposing spring. By means of a rod, *l*, and a lever, *C*, this reciprocating movement is transferred to a rod, *i*, an important piece of the machine, and represented apart. This rod vibrates in front of a toothed wheel, and fulfills the same office as the escapement anchor of ordinary pendulums. This toothed wheel is acted upon by clockwork enclosed between two plates. It would turn with a continuous movement if the teeth were not arrested, by striking against the rod, *i*. With this check it can move only when the rod turns aside under the action of the electro-magnet.



Anchor Escapement.

The toothed wheel is double. It is formed of two similar wheels firmly united together, in such a manner that the teeth of one correspond with the spaces in the other. When the rod *i* moves, it disengages a tooth of the first wheel, and the clockwork makes it turn; but the second wheel immediately encoun-

ters the rod *i* and the movement is arrested. At each displacement of the rod, the wheels will progress the half of a tooth further. The needle of the dial is carried by this double wheel and moves with it over the distance from one letter to another at each movement of the rod. Each wheel has 13 teeth, and thus 26 movements of the rod are required to bring the needle completely round. The



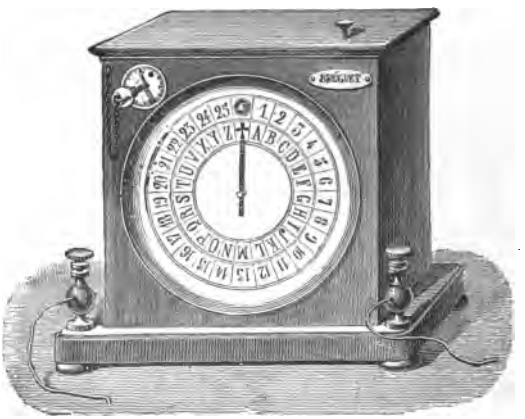
Dial Receiver.

machine is so constructed that the needle can be stopped at any letter desired, and kept there stationary as long as may be thought desirable.

The receiver is really a clock, in which the anchor, instead of being acted upon by an ordinary escapement, is acted upon by the electro-magnet, according to the will of the one who sends the message.

Consequently this machine requires to be operated with the same care as the most sensitive and precise time-pieces. That clerks, curious to examine the mechanism, may not rudely handle the delicate works, the whole is enclosed in a box, and only the dial is seen.

It can, however, be regulated from the outside, whenever necessary. By means of a button on the top of the box, the armature can be acted upon,



Telegraphic Dial.

and the needle stopped at any particular letter without the aid of electricity. Recourse is had to this procedure, when it is seen that from some cause or other the needle of the receiver is not in accord with that of the sender of the message, and is consequently giving false signals. Besides, at the end of the message the needle ought to be stopped at the final sign. Moreover, the different parts of the

machine, the tension of the spring, the speed of the rod, etc., can be regulated by means of particular keys. The tension of the spring is regulated by a little dial seen on the outside. But this work should only be done by competent persons; and only when time modifications have become absolutely necessary.

MANIPULATOR OF DIAL TELEGRAPH

It is as easy to work the manipulator as it is to read the receiver. It is simply and easily worked, however, because the inventor did not hesitate to use the necessary complications in the interior mechanism. Perhaps a few words will not be out of place upon the principle on which the machine is constructed.

In the centre of a dial divided into 26 divisions, works a winch furnished near the top with an index, which, in turning, comes successively upon each letter. The handle having at the commencement been gently drawn forward, is always turned in the same way and allowed to rest only on the letters wished to be indicated at the other end of the line. The dial is pierced with 26 holes, and a point which juts inward from the winch drops into one of these upon the exact spot corresponding to the letter. In turning, the handle carries around with it a wheel having a sinuous groove around its face near the edge. These sinuosities are equal; that is to say, there are 13 bulges and 13 hollows, regularly distri-

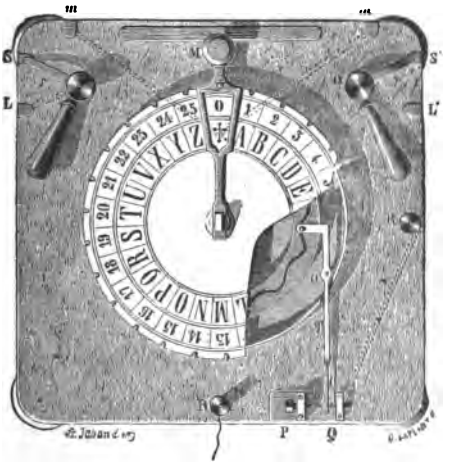
buted over the circumference. The head of a T lever entering the sinuous groove, follows its undulations as the wheel revolves in such a way as to oscillate upon its joint, *a*, with very regular back and forward movements. The lower extremity, *l*, of this rod alternately touches two points, of which one, P, is the pole of the battery, and the other, Q, communicates with the receiver, R. The lever itself is in constant communication with the line by the intervention of the grooved wheel.

Such is the process of manipulation. At the final sign, the lever not touching the pole, the current does not pass into the line. But if the handle is turned and placed upon the letter A, the lever, mounted upon the first bulge of the groove in the wheel, touches the pole, P, and the current enters the line. At the letter B, the lever, now fallen into the succeeding hollow of the grooved wheel, will no longer touch the pole, and the current will be interrupted, and so on. Each time that the handle of the manipulator passes from one letter to another, the current is interrupted and established, which is the condition demanded by the receiver. Consequently, if the two machines are well regulated and in perfect accordance, the transmission is simple and regular.

A complication of the manipulator exists, arising from the fact that each station ought to have at once a machine for receiving and another for dispatching, and that the same line should serve for the two machines. A telegraphic station is always in connection with the two neighboring stations. The

receiver is different for the two lines, so that a dispatch can arrive by each of them. It is the same with the alarm bells. But the manipulator itself is single and ought to serve for both sides. An ingenious arrangement of the interior mechanism satisfies these conditions.

In repose, the line, L, is upon the bell, S. A dispatch is announced, and the clerk moves a little



The Dial Manipulator.

handle, O, which places the line in connection with the bell, and connects it with the receiver, R, by means of the button, *m*, and the grooved wheel. The needle moves over the dial, and the dispatch is received. If a reply be desired, the small handle is placed upon the same button, *m*, which turns the large handle of the manipulator. This button, *m*, receives the current of the battery through the lever and into

the line. When the answer is despatched, the handle of the manipulator is placed upon the final sign, and the small handle is put upon the bell. These different pieces of apparatus are alike at the neighboring stations. If it happen that a station is to be passed by a secret despatch, the two small handles are placed in communication with each other by means of a small metallic plate used for direct communication between the neighboring stations. These metallic plates, which conduct the current from one station to another, are concealed by the plate of the indicator, but we have indicated them by dots in the illustration.

INSTALLATION.

In the management of railways the telegraph does not form a special service. Station masters and inspectors are the persons who are chiefly charged with the telegraphic correspondence. In isolated and unimportant stations, however, the persons thus employed are not always sufficiently taught in science to be skillful at their work; indeed, sometimes they are completely illiterate, and hardly know how to read and write. When, therefore, it happens that unskilled officials have to send messages, all the fantasies of orthography are employed, and that to an extent which causes the message to be completely incomprehensible. To obviate this inconvenience, certain conventional signs have been invented and are employed for ordinary despatches. Tables of these contracted signs are drawn up and

placed near the machine. Furthermore, a rule is laid down that the station to which a message is sent must announce the reception of the dispatch, and state that it is understood.

A telegraphic line for the use of railways consists generally of two wires. Of these the *common* one communicates with all stations, and the direct one only with the principal stations. Even the least important stations, those namely with which telegraphic communication is nearest, are furnished with complete apparatus. Usually this apparatus is closed, and communication along the line is direct; a compass only indicating the passage of the current. At certain hours, fixed by regulation, the station-master tests the state of the line; and if no message is traversing the wire, he makes certain signals, indicating that all goes well at his station; having done this, he re-establishes direct communication.

At the chief stations all the wires converge, from whatever side they may come, and each of them is attached to a special bell. But a complete manipulator can only be used in two directions—along a wire *coming to* and *going from* the station.

A railway, as we need scarcely explain, when finished, consists of two tracks, and trains going the same way run on the same track. At important stations only can a train change from one track to the other. In calculating the running of trains, a certain latitude is always granted, in order that no collision can be possible, even though there should be stoppages on the line. Bad management, or an unforeseen accident, however, may cause a train to

be delayed upon its way, and the line to become blocked, making a collision very probable. This emergency is provided against by special signals of distress, arranged for the purpose of preventing trains coming up and causing disaster. Collisions would be almost impossible if all these signals were faithfully given as prescribed. Unfortunately, however, railway employees often neglect certain of these signals, considering them superfluous, and hence arise accidents and mischief.

Sometimes, besides employing signals of distress, recourse is had to a peculiar expedient. The guard of the train is furnished with a kind of movable telegraph, a regular travelling station, completely fitted and enclosed in a box. When it is necessary to signal some unforeseen event, as a stoppage on the line, the guard opens his box, and draws out the conducting wires. By means of a jointed rod he attaches one of the conducting wires to the wire of the line, leaving the other in connection with the rails, which represent the "earth," or the common reservoir. The box contains a small, easily-worked battery and a manipulator. After his preparations are finished he can telegraph whatever signal he wishes. Upon reaching the line the current from the guard's battery bifurcates, taking at once two different directions, and reaching the two stations on either side. First of all the guard turns the handle of his manipulator four or five times, in order to proclaim the urgency of his case, and as soon as his signal is observed he can communicate his wants.

These movable machines, invented by M. Breguet,

RAILWAY CONDUCTOR SENDING SIGNALS.

are now rarely used. There is a reasonable fear that their use is dangerous. They introduce into the service novelties that may lead to mistakes. The stations, taken unawares, are rarely ready to communicate; and the dispatch being of an unusual character, is often lost, however urgent. Besides, these movable instruments, being rarely used, may get out of order, and fail at the moment when they are required. These considerations have led to the abandonment of the system of portable batteries for the use of railways.

When the railway consists only of a single track, the use of the telegraph becomes of imperative necessity. Before allowing a train to leave, the station-master is instructed to always ascertain that the line to the next station is clear. Generally the departure of regular trains is not thus signalled; but if there has been the slightest delay, intimation of it is at once given.

There exist upon railway lines depot stations, where locomotives, ready to act, are held in reserve, as well as spare carriages and other rolling stock. When a train is late, and news of the delay does not arive within six minutes of the time it is due, a message is sent to the station-master, to send a locomotive to inquire the reason. Before the invention of telegraphs these depot locomotives were had recourse to very largely and very constantly; but now the use of the telegraph enables the company to reduce the number of these more and more, and thus to economize material that is very costly to maintain.

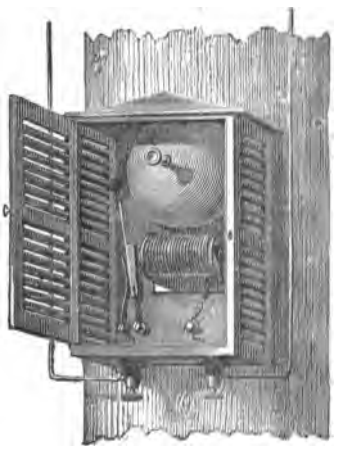
From what we have stated it will easily be seen what invaluable services the electric telegraph has rendered. The use of the wires to railways helps to diminish the number of accidents, to render the service more regular and certain, to reduce the expenditure, either by economy of rolling stock, or by the suppression of many depot stations, to make the management more free and bold, and enable it to make profitable use of the smallest circumstances —such as the return of "empties." These two magnificent agencies—railroads and telegraphs—work in such harmony together, afford to each other so much mutual support, that we cannot tell what the one would have been to-day had the other not been discovered.

SIGNALLING APPARATUS.

When a train is on its journey it is desirable that the officials who are not on it should know precisely where it is, or at least between what two stations it is running. If a station-master desires to know where a train is, he supposes, calculating its time of passage at each place, that it is near a certain station, and to that station he telegraphs for information. But besides this expedient, which results naturally from the existence of the telegraph, there is at each station an instrument that announces the approach of each train.

This contrivance is a bell placed on a post at the most frequented part of the landing-place. A wire

is attached to this apparatus, which is called the "indicator of trains." As soon as a train quits a station, the station-master sends a current into this wire, and the bell rings until the train arrives. After its arrival the electric current is stopped. By this means it is known that the journey has been accomplished. When the train starts afresh, a second station-master in like manner sets the bell of the indicator at the next station ringing. And so the process is repeated. There is, however, another method of accomplishing the same object. On certain lines the train itself, in passing over a certain rail, establishes communication and throws the electricity into the wire for the use of the indicators. This last arrangement, now the most common, is used when the station stands in a curve, the bends of which conceal the line from view.



Railway Indicator.

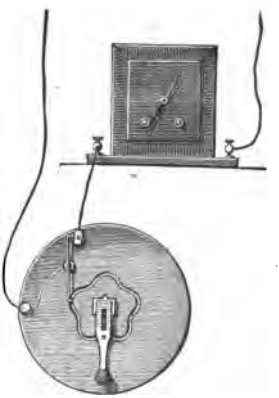
Indicators are also used in certain cases to protect trains from collision. When, for instance, a train is on the point of entering a station, it is necessary to inform every other train coming in the same direction that the track is not open. For this purpose a long wire is employed which connects the

station with a *disc signal* placed about a mile from the station, and which is used to work the signals. When the disc is in the direction of the line, it indicates that the track is free. When it is at right angles with the line, that it is blocked. Very frequently it happens, however, that the curves of the line conceal the disc from the signal-man, who consequently does not know the position of the signal; but a battery placed in the station communicates on one side with the earth, and on the other with an insulated wire, which runs forward to the signal post. When the disc is at right angles with the line, the wire connects with the earth, the current passes, and an indicator sounds in the station, which sound indicates that all is well. When the train leaves the station, itself, in passing over a particular rail, breaks the communication of the battery with the ground, the bell stops, and the disc returns to its normal position in the direction of the line. The same contrivance is used to announce that a train is entering a tunnel, and the bell sounds as long as the train is underground.

A special battery is used for those instruments. The signals they make have the great advantage of being loud, and therefore certain not to be overlooked. This is the cause of that horrible noise that sets one's teeth on edge, which we hear on the movement of trains on a number of parallel tracks.

For greater security it is desirable to know how far off a train is, even when in full speed—and the signals employed for this purpose are of great use to

trains in distress, especially when the movable battery, already described, will not act. For this purpose the distances between the stations are divided into sections, the distance between two stations of departure forming one section. With the view of securing this object, special instruments named *monitors*, are ranged upon telegraphic posts at a distance of about two and a half miles from one another. A special wire runs from the station-master's office, traverses the line, passes through the monitors, and runs on to the middle of the section, where it goes into the earth. This wire is constantly traversed by a permanent current, and the monitors thus communicate with the receiver of the nearest depot station.



Monitor.

The monitor is enclosed in a fixed box, and consists of a compass, the vertical needle of which is movable between two bells. The machine, in fact, forms a sort of receiver. Beneath it is a manipulator formed as usual with a grooved wheel, worked by a handle, and used to break and close the electric current. This wheel is constructed in such a manner that in the first monitor it has one sinuosity, in the second two, in the third three, and so on. When a train is in distress, a road laborer runs im-

mediately to the nearest monitor. Here he opens the box and gently turns the handle completely round. In our illustration, the wheel displays five sinuosities, and consequently the machine indicates a distance of about twelve and a half miles from the depot station. One entire rotation of the handle interrupts the current five times. The receiver at the depot station is an ordinary dial, bearing figures in place of letters. When not in action the needle points to 0; but after the current is interrupted, the bell sounds, and at the same time the needle moves and stops at No. 5. This informs the station-master that near the fifth monitor, between ten and fifteen miles distant, he will find a train in distress, and requiring assistance. After the signal has been received, the needle is replaced at 0, which again reproduces a series of interruptions of the current. These second interruptions tell back upon the monitor, and make its needle oscillate and strike on the two bells. Perceiving this the road laborer knows that his appeal has been heard. This sort of signal is generally repeated twice, in order that all chance of mistake may be avoided.

Even this, however, is not all. Excellent as it is for the purpose of demanding help, this contrivance is found to be useless for preventing accidents. In 1855, M. Bonelli attempted to establish communication between trains running on the same track. His invention made a great noise, and it was supposed that a universal preventive against accidents had been found. Experiments made first at Turin, then in France, between Paris and St. Cloud, proved very

successful, but the system was not adopted, and the general infatuation in its favor gradually disappeared before cool and clear reason. It was found better to compel the officials to exercise anxious and continuous care, than to allow them to believe themselves always safe, for even the most perfect machinery was liable to become disarranged at the very moment it was desired to act. As the invention, however, was a curious one, a few words of description regarding it may be interesting.

M. Bonelli's machine was very simple. Every train carried in a separate compartment a complete set of telegraphic apparatus. The battery of this apparatus communicated on one side with the earth by the medium of the axle-trees and rails, and on the other side by means of a rubber with a bar of iron laid down in the middle of the track. This bar of iron was insulated from the ground, and extended along the entire length of the line, all the trains running on the same track being by means of it put into communication with each other. Some people thought that by improving the invention, a little knowledge might be obtained of the exact distance between any two trains running the same way. M. Bonelli's invention was considered perfect and capable of being actually used on railways.

Many attempts were from time to time made to enable passengers to put themselves into communication with the guards or conductors, with the view of preventing crimes which are frequently committed in isolated compartments, or accidents that may happen to travellers out of reach of help.

Many systems have been proposed for this purpose, both in England and in France, and after innumerable experiments, some have actually been adopted. In England, the subject was taken up by Parliament, and an act was passed compelling railways, under penalties, to supply adequate means of communication between guards and passengers, on trains that travel twenty miles without stopping. This act, however, owing to the laxity of the authorities, has been carried out to only a very limited extent. The Northern Railway of France, however, has had a system of communication in actual operation for some time past.*

A wire runs above the carriages and connects two vans, one at each end of the train. An electric battery and an alarm bell are in each of these vans, and the wire passing into the bells connects the similar poles of the batteries, while the other poles connect with the earth. In this position each battery sends into the wire an equal current, and these two meeting each other, destroy one another. Each compartment of the carriages contains a button or handle, so constructed that any person in distress, by pulling this handle, can put the wire in connection with the earth. When this is done, the two

* The European passenger coaches, being divided transversely into compartments, having no inside communication with each other, completely cut off the passengers from any assistance from the officials, in case of assault or distress. In the United States coaches, the communication is always open and free throughout the whole length of the trains, rendering an electrical connection less important than in the European coaches.—A.

currents no longer act against each other, the alarm bells are rung, and at the same moment two white signals rise above the carriage in which the handle was pulled, and point out to the guard where help is required. The wire passes from one carriage to another by means of a particular piece of metal, so arranged that if there is any breakage in the train, communication with the earth is immediately established.

Apart from this system, which is employed on only one line, the French companies have rejected almost altogether machines like that of M. Bonelli which tend to prevent accidents. Railway companies have preferred to run the risk of accidents, rather than create less care among the railway hands. Many other machines invented for similar purposes were proposed and thoroughly tried. Public opinion approved of them, although it was found that the greater part of them could not be adopted. Such apparatus demands from the officials incessant attention, and a delicacy of handling rarely to be met with among railway employees. The machine moreover to be available must always be in order. Leaving theoretical considerations out of the question, it would be well if attention were turned to the actual dangers of the roads, and to the discovery of infallible means of preventing them. In the meantime, it is well known that if prudence be observed and none of the wise instructions required by the rules neglected, collisions between trains may always be avoided. If we examine the causes of the railway disasters that have moved public feel-

ing, we shall almost always find that they are to be attributed either to imprudence or forgetfulness. Now it is the station-master who allows a train to depart without ascertaining the state of the line. Now it is a workman repairing a line and neglecting to observe the signals, or regulations laid down for his guidance. Negligence of the employees is almost always the first cause of these frightful accidents. No machine, however perfect, can become a substitute for proper care and attention.

Contemplating those railway disasters which suddenly plunge numerous families into mourning, public sentiment is moved to righteous indignation. Let us imagine one of these collisions, whose details are often suppressed by policy and prudence. Two trains meet, running at full speed; the strong locomotives break into shivers like glass, the cars, suddenly obstructed, run into each other; the buffers are twisted and pierce the carriages; the engineer and fireman are thrown out or crushed; passengers tossed upon one another, and buried under the ruins. Groans and lamentations arise all around. Some are dead, others are dying; those who have escaped inveigh against the company, shouting and demanding satisfaction. Each one thinks of himself, of those whom he has left, of those who await his arrival. The railway officials, whom these loud accusations terrify, run about seeking to re-establish order, and prevent new misfortunes. Meanwhile the country is naked, and help remote. Relief comes slowly. Often fire adds its terrors, and increases the horror of the scene. Such accidents

are sufficiently frequent to make us demand that science shall, if possible, supply the means of preventing such disasters. Such demands are made, but the only certain and reliable means of prevention are prudence, and the rigorous performance of all duties. In vain electricity applies itself to meet these exigencies, in vain special signals are invented, in vain powerful and ingenious machines are devised to stop the progress of the trains—the success of all these expedients, excellent in theory, must rest always upon the good condition of the machine, and the care and promptness of the employees. It is to be feared that the effectiveness and ingenuity of such machines would only afford additional pretexts for negligence. Happily, upon the whole, accidents are comparatively rare; and it is to be hoped they will become less and less frequent, by each official learning more and more his own particular responsibility

CHAPTER V.

CONSTRUCTION OF TELEGRAPH LINES.

THE construction of a telegraphic line is a work of no ordinary difficulty, and the engineer charged with this work must show more zeal and science than at first sight appears. He finds himself under the necessity of superintending a multitude of men of all trades, and impatient of restraint; and, the service of telegraphy demanding works of quite a peculiar kind, he has often great difficulty in getting workmen to faithfully execute details, the utility of which is not apparent to them.

The first care of the engineer is to explore in detail the country through which he must carry his telegraphic line. He must travel over it many times, and study well the arrangement of its waters, and also the prevailing winds. He must know the valleys, the mountains, the forests, the principal roads, and the cross roads; all the circumstances, in fact, which may, in great or small degree, influence the normal conditions of an established line, or assist in the construction of a new one.

Having amassed this information, his next duty

is to make a drawing of his route for the line, in order to determine the principal points where it must pass, the villages it must traverse, and the roads it must follow. He then has to mark the points where he will place his posts. Generally, to render oversight more easy, the line is planned to run along the highway, but in mountainous countries it is made to avoid the windings of the road, and the engineer forces it to go in a straight line, taking good care, however, to place the supporting posts in easily accessible places. He must so arrange them that the line will present no sudden bends. Where curves are necessary, they are designed as large and long as possible, so that the solidity of the supports may not be endangered. At the crossings of roads the line must be high enough to be above the reach of passing carriages.

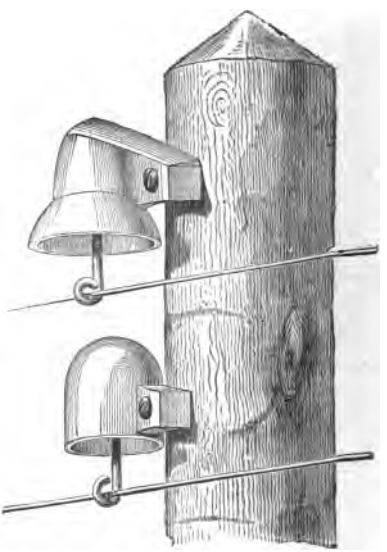
After finishing his drawings, the engineer pickets the places for his posts along the line. The posts should be placed at a distance of 150 to 200 feet apart, according to the number of the wires; but new supports can be added as necessity may demand. When narrow valleys or rivers are to be crossed, he places two strong posts at two salient points, one on each side, and between these he can, if he likes, suspend a wire of hundreds of feet in length.

In France and England the posts are often prepared to resist all varieties of climate and temperature,* by being steeped in a liquid which protects

* In the United States, good and durable timber is yet tolerably abundant, and the need of such precautions against decay is hardly felt.—A.

them against rotting, and they afterwards receive two coats of paint, and sometimes a top covering of slate.

Afterwards they are planted firmly in the soil, in a deep, narrow pit, into which the earth is firmly beaten down around the post. The net cost of a post thus implanted is, in Europe, about fifty-five cents for a support of eighteen feet, and about $1.50 for a post of thirty feet. Three lengths of post are usually employed in France, viz., nineteen feet, twenty-two feet, and thirty-two feet, their thickness necessarily depending upon their height. When the supports are placed in the earth in good condition they last a long time. Cups of porcelain or glass are set at the tops of the posts, for the purpose of sustaining the wires, and insulating them from "earth." According to their uses, these cups differ in size, shape, etc. Besides the ordinary cups, supports are used, shaped like mushrooms, when it is necessary to stop the wire; and shaped like

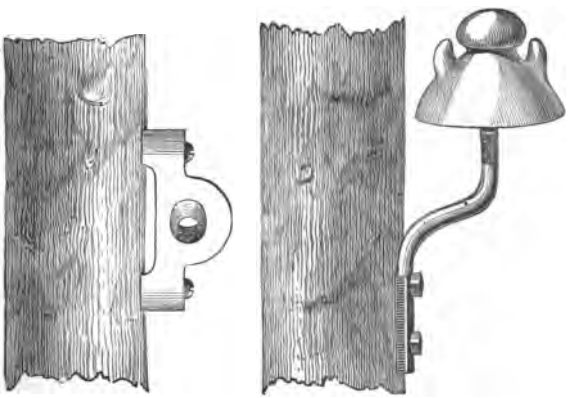


Bell-shaped Insulators.

rings when the wire, dragging its support, might risk the breaking of the hook.

The electric wire is made of galvanized iron, the thickness of which varies from .31 to .34 inch. One mile of this wire weighs about 373 pounds. It is by its weight that its quality is judged. Where curves occur, and where the posts should be required to support as small a weight as possible, wire is employed only .31 of an inch diameter, which does not weigh more than 254 pounds for a length of one mile.

After being manufactured, the wire is rolled up into coils of about 650 feet in length, which are

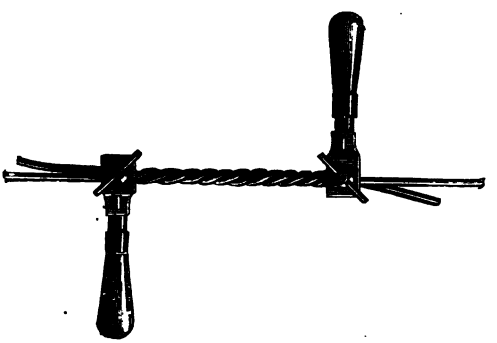


Different Forms of Insulators.

easily unrolled when it is necessary to stretch it along the posts. To connect the coils of wire, instruments somewhat of the character of a vise, as depicted on the next page, are employed. When the line traverses a town or a village it is upheld by

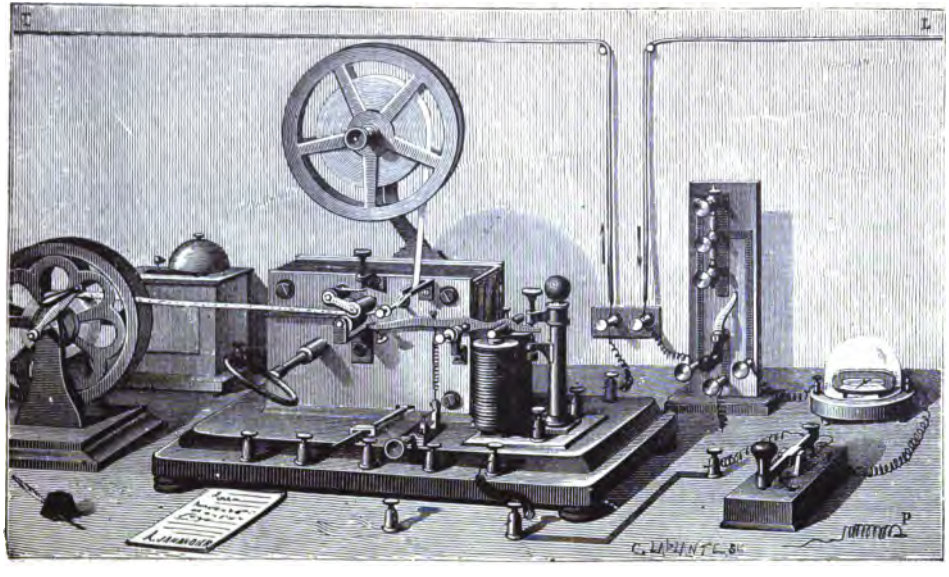
a "support," furnished with porcelain cups, and fixed into the walls of the houses.

All the preparations being at length completed, camp workshops are formed, comprising in each five men and a foreman. One workman walks out in front, unrolling the coils of wire and joining them together by twisting the ends; two others follow, fixing the cups on which the wire is attached, while a fourth follows, charged with stretching the wire by means of stretching-jacks. These machines, placed at the distance of about 1,600 feet from each other, are formed of two metal ratchet-wheels, the



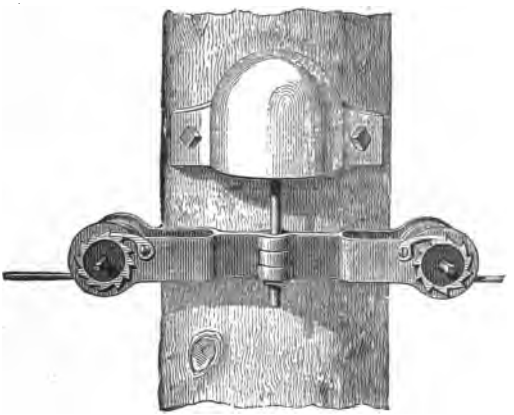
Twisting the Wires.

wire being fixed in a hole which pierces the cylinder. The wire is pulled vigorously, first by the hand, and then by means of a tackle and vise. Finally, the wire is cut and the ratchet-wheels turned to regulate the tension. For this stretching, a certain apprenticeship is necessary, and the foreman is oftenest with the workman engaged in it, directing him and helping him. If the tension is not strong



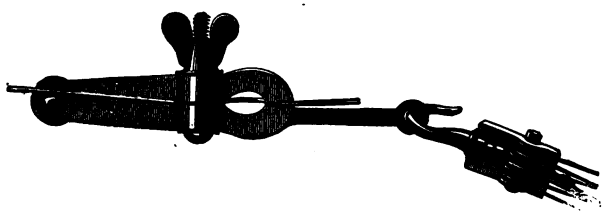
MORSE TELEGRAPH STATION.

enough, the wire will sag, and under the action of the wind will strike the other wires, as well as other objects that are found in the way. If, on the other hand, the tension is too great, the wire will either



Tension Ratchets.

break, or it will strain upon the posts too much—seriously endangering their stability. Many experi-



Stretching the Wire.

ments and close study have been directed to the finding out of the best tension to give to the wire under given and well known conditions. It has been

noticed that under the simultaneous action of tension at the extremities, and of weight, the wire takes a curve more or less deep. The form of this curve is well known, and its flexure easily measured. It is stated that for a wire .16 of an inch in diameter, the most usual tension is a weight of 154 lbs., which produces, when the posts have an interval of 230 feet, a maximum bend of three feet in the middle. Behind the first workman, at the distance of a few miles, moves another, whose business it is to rectify the standing of the supports, and to regulate the tension of the wire by turning the ratchet-wheel with a winch.

A working party of five, thus working together, stretches about four miles of wire a day. When the line consists of several wires they are placed at the same time, and a larger number of men are employed.

Generally the cups are placed alternately on either side of the posts, in order to balance the action of the wires upon the supports; but where there are angles they are all placed on one side. In the latter case all the wires exercise a violent traction and tend to overturn the support. When this occurs, the posts are propped by sustaining posts, or by ropes made of iron wire twisted together, and strongly fixed to the ground, so as to draw the post back from the side on which there is danger of its falling.

Who has not heard the noise which a telegraphic wire often makes? This grave sound, monotonous, sometimes, and often musical, is due to the wind,

causing the wires to vibrate like the strings of an Eolian harp. Sometimes the vibrations are so powerful as to make the earth under the posts tremble, and even to shake the buildings to which the wires are attached by the trusses. Upon ordinary routes this is no great inconvenience, but it proves otherwise in towns. In order to reduce the vibration as much as possible, thick plates of caoutchouc are interposed between the truss and the wall, which, precaution suffices to deaden all vibration.

Engineers avoid as much as possible leading a line through a tunnel, because permanent damp is unfavorable to the transmission of electricity. Nevertheless it is sometimes necessary to traverse tunnels of considerable length. In such cases each wire is covered with a thick layer of gutta percha, made flexible like caoutchouc, by means of rosin. The wires are supported on the walls, or they run along a trench, cut in the side of the vault. In the same way when it is necessary to traverse wide courses of water, the wires are united together and covered with gutta percha.

The net cost in France of a line of two wires is about $50 per lb., which figures include the fitting up of the offices and the purchase of the machinery.

After the line is in operation it is submitted to a daily examination. Inspectors, resident in the localities traversed by them, visit them every day, keep them in good order, and make the necessary repairs. They also visit, according to the orders they may receive, the different parts of the section, and superintend the testings. When the line is

finished along the rails, the agent mounts into the look-out at each station, and from this perch carefully surveys the wire. Should he perceive any irregularity, he descends at the nearest station and walks back to the spot that requires his care. Such is the mode of constructing aerial telegraphic lines in France. At present, in that country, there are more than 63,000 miles of telegraph laid and in operation.

If the electric telegraph was invented in England and America, aerial lines were first thought of in Russia, where this new idea was at first received with discouraging sneers. The Emperor Nicholas, having seen a telegraph established in 1834 by M. Schilling, expressed his desire that a similar communication should be formed between St. Petersburg and Peterhoff, the Imperial residence. A commission was appointed to carry out the scheme, but great difficulties stood in the way. It was proposed to lay a cable at the bottom of the Gulf; but science was not then sufficiently advanced to carry out this idea. M. Schilling proposed to lead the conducting wire upon posts along the Peterhoff; but undisguised sarcasm greeted this proposal, One of the members of the commission, in fact, in a fit of scornful indignation, even cried out: "Ah, monsieur, your wires in the air are quite ridiculous." At the present day, the idea so much ridiculed has become a gigantic reality, and a network of these "wires in the air" covers already nearly all the globe.

STATIONS.

The wires of a line are held up at the entrance of the telegraph stations by ring supports, and they penetrate into the interior without touching the walls, by means of openings provided for the purpose. Inside the station they are ticketed and classified, and each of them is carried to a manipulation table, traversing on their way a lightning-rod, then a fixed galvanometer, and finally a communicator. This is a small handle, the centre of which constantly communicates with the line, and can place the line wire at will upon one button or another of the small instrument attached. By means of this the current can be thrown either into the bell, into the receiver, or into the direct communication. Before entering into the receiving apparatus, the wire, as we have already explained, traverses the manipulator.

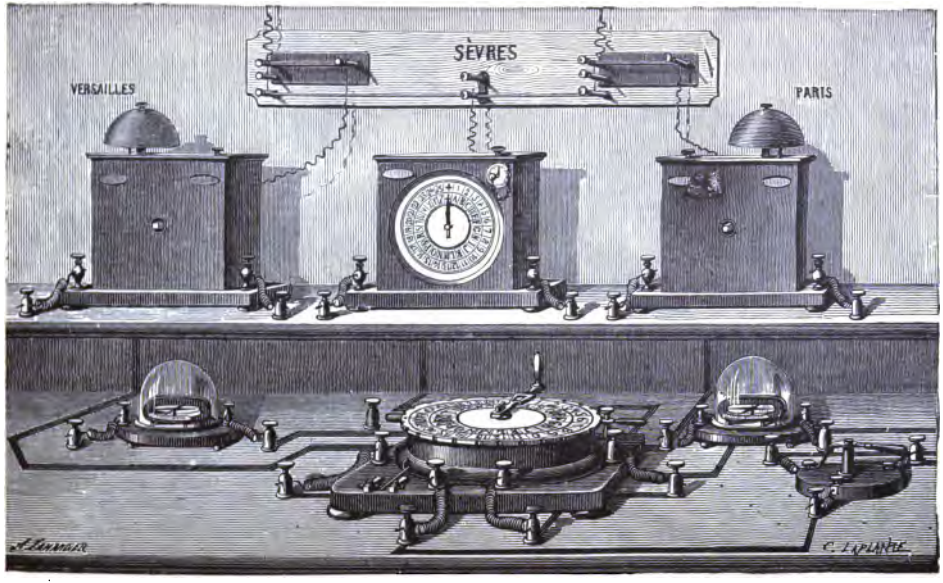
Our illustration represents the manipulation table of a main line station in which the Morse system is used. The line wire is represented by the letter L. It traverses the different machines, and afterwards is attached to a great wire T, which crosses the table and communicates with the earth. P is the wire of the battery detached exceptionally from the key.

In intermediate stations the arrangement is apparently more complete than at the extremities of the line. But the principles are the same, and it is always easy to understand the run of the lines. Having to communicate with both sides of the line, the machines are made double. It is necessary to establish communication only with the side from

which the message comes, and to place the other side with the bell, so arranged that it will sound if any communication arrive. Besides, the station wires have to be arranged so as readily to establish direct communication by means of communicators.

For dial telegraphs the arrangement is slightly different. In intermediate stations, the manipulator serves for both directions, which renders the interior more complicated. In railway stations the manipulating table is surmounted by shelves, upon which the instruments are ranged. Only the manipulator is within reach of the hand; the battery is placed under the table, and the different communications between the instruments are closed by plates fixed in the table, which cannot be deranged by the operator. Ordinary stations possess, besides Morse instruments, a complete dial system in correspondence with the railway stations, for it happens sometimes that these stations transmit private despatches.

Too much care cannot be taken to make sure of the communication of the battery with the ground. In order to ensure this object completely, a metal wire or a cable, formed of wires twisted together, connects the ground wire with large plates of zinc, very deeply sunk in damp earth, or surrounded by a mass of bakers' ashes or charcoal, as is done with lightning-rods. Often, also, when circumstances permit, the cable is connected with the metallic tubes which distribute the illuminating gas.



FRENCH RAILWAY TELEGRAPH STATION.

SUBTERRANEAN LINES.

Along roads which cross mountains, and in towns and valleys, aerial lines are easily watched, are cheap to construct, and do not ordinarily lose much electricity on their way through the air. But the same cannot be said in respect to wires passing through great cities. Telegraph wires are objectionable in the streets of a fine city. They disfigure the most beautiful spots, and destroy the artistic effects of the long, beautiful, and regular thoroughfares, which are so much in fashion at the present day. Besides, the wind vibrates them, and the sound cannot always be deadened. Moreover, absolute danger arises from them, for, should the wires or their supports break, people would run the risk of being injured or killed. Aerial lines, however carefully constructed, are liable to be suddenly broken in tempestuous weather. These considerations induced telegraph engineers to turn their attention to subterranean wires. These also were the considerations that, in 1845, induced the French authorities to take into consideration the propriety of concealing the numerous telegraphic wires, which, stretching around the Tuileries, at one time disfigured the harmony of that superb palace, and to consider the best means of placing under the ground all the wires converging about Paris.

When the telegraph was first invented aerial lines seemed impossible, and subterranean networks and wires were constructed. Prussia and Russia organized their systems upon this plan. But it was soon

noticed that the soil had a tendency to rust the wires and destroy the protecting coverings. Subterranean wires were accordingly given up, except where their employment was absolutely necessary.

In order to protect the wire from this destructive action of the soil, a thousand means have, from time to time, been proposed. Some inventors covered the wire with gutta percha, and afterwards with bitumen; but the gutta percha peeled off and fell into powder, and the bitumen split up under the action of the gas. The employment of a particular kind of bitumen was, in spite of this, regarded for some time with a sort of infatuation. Experiments made with it proved perfectly successful on the Rouen railway, but at Paris the telegraph cables could not exist in connection with gas pipes.

At length a process was invented by M. Baron, which seemed to promise well. According to this system, seven very fine wires of copper are twisted together, and covered with four layers of pure gutta percha, alternately with four layers of Chatterton's composition—a substance made in England for submarine cables—the exterior being covered with a thick tarred coating, very closely pressed over the concentric layers. Subterranean cables are identical with those which are laid at the bottom of the sea. Thirteen of these cables, independent of each other, and insulated by their different coatings, are introduced into a cast-iron pipe, the joints of which are closed with lead. The cables are thus preserved against destructive contact with the neighboring earth. In order to give facilities for

testing the state of the different lines from time to time, and replacing them when needful, peep-holes are made in the conducting tube, at about 325 feet apart from one another. At every fifty paces the tube is cut, showing an aperture a foot and a half long, which is protected by a slide or cover three feet in length, that enables the inspector to open or close the orifice. By means of this contrivance the wire is examined, and the faulty part discovered and repaired.

The Central Telegraph Office of France is at Paris, in the Rue de Grenelle, St. Germain. Departing from this point, the line is entirely subterranean so far as the Rue Royale, where it descends into the main sewer, and branches off to the different quarters of the city. The main line of the wire, suspended from the vault, follows the line of the great sewer, and does not emerge above ground until it reaches Asnières. It there joins the aerial circuit, which distributes the communications to the different railway stations of the city. In 1864, a second system, in all respects similar to the first, was established upon the left bank of the Seine. The wires, which were seventy in number, entered Paris underground, at the barrier of the Maine, proceeded along the Rue de Grenelle, and descended into the Catacombs. There, suspended in the vaults, they ramified to all the stations on the left bank of the river, and finally ascended again to the upper air at Montrouge, where they rejoined the aerial lines

SUBMARINE LINES.*

In 1849, a Frenchman named M. Brett carried into execution the idea suggested by Mr. Wheatstone. A cable was constructed in England, was immersed in the sea at Calais, and some signals were exchanged through it. But the cable soon broke, and another attempt had to be made. The causes of the rupture were diligently studied, and the second venture was made with better precautions. Its success was complete. Submarine telegraphic communication was established, and the cable from Dover to Calais, laid in 1851, worked well until 1866, when it was broken by a violent tempest. It

* The idea of submarine telegraph lines existed amongst scientific men long before it was successfully realized. So early as 1797 Don Francisco Salva appears to have proposed one between Barcelona and Palma, in Majorca. In 1839 Dr. O'Shaughnessy experimented upon the subject in India. In 1840 Professor Wheatstone presented to the English House of Commons a plan for constructing and laying a cable between Dover and Calais; but his ideas were at that time too far in advance of those of other scientific men to be received and adopted. In October, 1842, Professor Morse laid a wire between the Battery, in New York, and Governor's Island, and worked it successfully the following morning, until it was drawn up by the sailors of a vessel in raising their anchor, and a considerable portion of it cut out and carried off as a prize. In the same year Mr. Samuel Colt laid and operated successfully a cable between Coney and Fire Islands and the city of New York. The first submarine telegraph wire successfully laid in Europe was shortly after, by Lieutenant Siemens, of the Prussian Artillery, and connected Dentz with Cologne, about half a mile distant. This wire was insulated with gutta percha; the first time this substance was used for such a purpose. These successes rapidly educated the world to the idea that such enterprises were practicable on a much larger scale.—A.

was twenty-five miles in length, and although during the fifteen years it existed it had many times been struck by the anchors of ships, it never required very serious repairs.

As soon as this enterprise, then considered gigantic, had been successfully consummated, other and longer lines were projected. Dover and Ostend were united by means of a submarine wire, and afterwards each country was united with the neighboring countries, until every sea was traversed by a telegraph cable. The public became more and more familiarized with submarine cables, and were no longer baffled by any obstacles. In 1859 an attempt was made to connect Egypt and the Indies, by traversing the Red Sea and the Gulfs on the South of Asia. To ensure this object it was necessary to immerse a cable more than 3,000 miles long. For a time this most gigantic design seemed crowned with success, but the triumph was short; in less than a year the cable ceased to work.

About the same time, in 1858, the first Atlantic cable, destined to connect the Old World and the New, was laid between England and America by Cyrus W. Field, an American merchant. The electric wire employed for the purpose was nearly 2,000 miles long. This wonderful venture at first partially succeeded. Several signals were exchanged between Valentia and Newfoundland, the first despatch being "Glory to God in the highest, and on earth, peace and good will towards men!" Thus gravely and solemnly was correspondence between the Old and the New Worlds inaugurated. Numerous congratu-

lations were exchanged between England and the United States. Enthusiastic meetings were held at London and New York, and at many other places on both sides of the ocean. The joy was universal; but at the height of the rejoicing the cable failed, and the public hopes were shattered. This proved a fearful disaster; sad disappointment succeeded to the jubilation, capitalists retired from the enterprise, and the companies lost all spirit.

Failure, however, did not long damp the ardor of the enthusiastic originators of the enterprise. The bold idea was not given up. On the contrary, researches were made which gave hopes of future success. In consequence of these, the project was again taken in hand, and in July, 1865, another attempt was made to lay a new Atlantic cable. The Great Eastern, which carried this cable, after accomplishing a part of her onerous task, was overtaken by a violent storm, and being held by the part of the cable already immersed, rolled and tossed fearfully upon the waves. In vain the vessels that accompanied her strove to render assistance. The monster ship, driven by the tempest on the one hand, and held by the cable on the other, was placed in a very dangerous position. As may be imagined, there was an immense strain upon the wire, a strain which could not very well be diminished. At length the wire broke, and sunk to the bottom of the sea. Thus failed the second attempt to unite England with America. In July, 1866, a new attempt was made, which proved entirely successful. Favored by good weather, the Great East-

ern managed quietly to lay the cable at the bottom of the ocean. Communication between England and America was found to be complete, and since that time the cable has worked regularly and uninterruptedly. This great event, so important to the the whole world, was accomplished almost without notice. Germany was then convulsed, Europe regarded the banks of the Rhine with apprehension, and the needle-gun engaged universal attention.

On its return, the Great Eastern was employed to fish up from the bottom of the sea the lost part of the cable of 1865. After weary search and effort, the cable was at last found, completed, and safely relaid; so that now two Atlantic cables connect England and America, each of which works perfectly. In addition to these, a French cable has very recently been completed, along which the Emperor Napoleon sent his congratulations to President Grant.

On the return of the Great Eastern to England, after her double success, there were great fêtes and rejoicings. Every one appreciated the importance of this triumph of skill and perseverance. The officers and men who had taken part in the expedition were feasted and warmly received on all sides, and at the French Exposition, the English company were presented with a medal of honor of the first class.

Previous to the laying of the Atlantic cable in 1861, there were nearly 11,000 miles of submarine cable laid in different parts of the world, nearly

7,000 of which had failed, the cables having in many cases been destroyed.

The longest cable at that period was that from Singapore to Batavia in the East Indies, which was constructed in 1859, and was about 225 miles long. Since that time several cables have been laid, but the official returns have not been published.

After the disaster of 1858, the English Council of Commerce and the Transatlantic Telegraph Company appointed a commission consisting of the most illustrious men of science in England, to study the condition of laying submarine cables. During eighteen months this commission devoted itself to a series of studies and inquiries, and in 1863 it published a voluminous report, full of facts and speculations, theoretical and practical. This report is at present the most complete résumé of the history and progress of electric telegraphy published. A multitude of secondary considerations and phenomena are treated in connection with the chief phenomena, and complicate the report wonderfully. All the main and important questions, however, are studied with care; all the phenomena are arranged and classified according to their relation with the phenomena already understood, and if this "Blue Book" does not give a complete solution of every difficulty, if it does not prescribe remedies always efficacious, it at least presents the immense advantage of making known the dangers to which submarine cables are liable, and the subordinate facts relating to construction and management which ought never to be neglected.

A submarine cable consists, in the first place, of an electric conductor, forming, as it were, the soul of the cable, and consisting of wires of copper, twisted together so as to form a single stout cable. At the beginning of submarine telegraphic enterprises, one cable enclosed several conducting wires,

Submarine Cable.

each of which had a special destination. Each of these wires was surrounded by an isolating substance which preserved the electricity as much as possible in the wire, and prevented its escaping. This isolating substance varied with the cable. Generally Chatterton's composition, already spoken of, was used—a mixture of gutta percha, wood-tar and resin, which has the property, not possessed by the other insulating materials, of adhering firmly to the copper wire. Upon the wires were placed several layers of this material, and above it was placed a series of insulating layers, either of hardened caoutchouc alone, or alternating with Chatterton's composition. Finally, to protect the cable and to provide against blows and accidents, the whole was first covered with tarred hemp, firmly wound, and then with a series of thick steel wires, which formed the exterior covering.

After the publishing of the Blue Book of the English commission, opinions slightly changed respecting the construction of submarine cables, and a single copper wire cable instead of several is now used. This single cable is generally composed of five smaller wires twisted together, so that if one of them breaks, telegraphic communication is not thereby destroyed. This compound copper wire of the cable is surrounded with insulating material.

This species of cable, which has been employed with slight modifications in most of the experiments that have been attempted, is very heavy. The first transatlantic cable of 1858 measured .63 of an inch in diameter, and weighed about 2,200 pounds per mile, a weight justly reckoned enormous. Many competent persons think that submarine cables should be at once very strong and very light.

New models have lately been constructed more manageable, more easy to lay, but also more rapidly destructible by the corrosive action of the sea. Experience will tell which is the better of the two. The transatlantic cable laid in 1865, and relaid in 1866, was as heavy, but that which was laid new in 1866, was much lighter, the diminution in weight arising from the lighter exterior steel covering. The cables, however, were essentially of the same make.

Down to recent times England had a monopoly of the construction of submarine cables, and other countries have been its customers. A factory, however, was set up a few years ago at Beson, near Paris; and since its origin it has constructed cables

which some consider equal to those of England. These cables obtained a prize at the French Exhibition of 1868, over the English cables; but it must be added that the English have produced nearly all the telegraphic cables actually working on the globe, and all who have made a special study of the subject award the palm to England.

On leaving the factory the cable consists only of the wire with its insulating coverings. At the port of embarkation the external envelopes of hemp and steel are added. Very ingenious machines are used for this purpose; but different engineers use different apparatus. As the cable is being made it is necessary to test, at almost every step, whether it gives free passage to the current. If the covering makes no change in the resistance to the electric current the work is satisfactory; but if it increases the resistance it proves that the insulaing covering has broken, and that the electricity passes through the aperture into the external metal covering. In such case the wire has to be cut, and the fault rectified.

When the cable has been made, it is tested—always an extremely delicate operation; then it is embarked and is ready for laying. Prior to this step being taken, the route which the vessel is to follow, and as near as possible the character of the bottom of the sea, are carefully studied. The success in laying the Atlantic cable must, in a large measure, be attributed to the study of the ocean bed. Investigations proved that all the way between Newfoundland and Ireland there existed an almost

horizontal bank along the bottom of the Atlantic. The ridge had, so to speak, been planed level by the lower currents, and it formed a sort of submarine horizontal plateau, smooth and regular, separating two deep submarine valleys. Along this bank the cable was laid, a bank which has since been called the telegraphic plateau.

When ready for sea, the cable is packed in the hold of an ordinary steamship. It is rolled upon one or more cylinders, each of which is placed in a special compartment. As the cable constitutes the greatest part of the ballast of a vessel, it is necessary to replace by water the weight taken away, in proportion as it disappears in the sea. This keeps the ship always ballasted. On leaving the hold, the cable is received upon two strong cast-iron wheels, around which it turns three times. These wheels are furnished with powerful brakes to regulate the movement, and prevent the wire being paid out too rapidly. In order to prevent the cable being heated by friction, about twenty workmen are constantly employed throwing water upon the wheels and brakes. After leaving the wheel the cable runs out on a long iron roller, placed at the stern of the vessel, where it can move easily from right to left, according to the motion of the ship, and from this long roller it descends into the sea. Indicators placed on the wheels announce every instant the length of the cable that has been paid out.

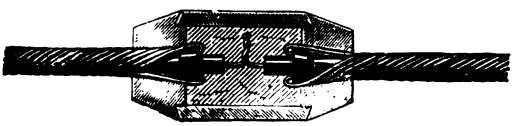
On board the vessel are placed telegraphic instruments, which communicate with the land, and by means of which, at every moment, the state of the

cable can be tested. Incessant care, of the most anxious description, is required, to bring the operation of paying out to a successful close. If the cable rolls out too quickly it will knot itself in the depths of the sea; if too slowly the part already immersed exerts an enormous traction, and when this continues increasing for a time, the cable breaks. The wind, the waves, the tossing of the vessel, are all causes tending towards breaking the cable, or more or less towards rendering the paying out irregular. In spite of all these serious practical difficulties the progress of submarine cable-laying has succeeded, and the aim sought after has been attained after numberless and expensive trials. In this, as in all things, perseverance has been one of the principal conditions of success.

When a cable has been broken, the largest part possible should be sought for and rescued from the sea. This should be done in the first place for the sake of economy, because the remains can be used in the construction of new cables, and in the second place for the sake of forwarding scientific inquiry; because the causes of the rupture and the reasons of the failure can best be told when the broken fragments are recovered. Searching for a broken cable is always a long and trying operation. A vessel drags a grappling iron backwards and forwards over the place where the submerged cable is supposed to be, until the hook fixes itself. If the grappling iron will not move at all, it is known that it is caught by a rock, but if it is fixed in one direction while it will be sliding in another, it is known to be fastened

in the cable, and the grappling iron is dragged up till the searchers find what they seek.

When the cable has been broken, or when two vessels moving in different directions, each lay one half of it, it is necessary to connect the ends. For this purpose the extremities are enclosed in an



Lair's Method of connecting Cables.

iron box, and the steel wires of the exterior of the cable are bent back in the form of a sort of hook on each side, so that the ends may not slip back out of the box. The interior copper wires of each end of the cable are then laid bare, and the two twisted together and firmly soldered. A mass of melted gutta percha, which is the best insulating substance known, is next poured into the interior of the iron box. Finally, having hermetically sealed the box and soldered down the lid, a perfect joining is obtained. This process, invented by Mr. Lair, occupies only 25 minutes in its accomplishment, when done under the best conditions, but it has not been attempted in France. The French strip bare the two ends of the wire, connect them by an ordinary twist, then cover them with insulating matter and tarred hemp, and finally with iron wire, which they solder to the steel wires of each extremity.

In France the telegraphic administration has created a particular branch of the service, devoted spe-

cially to the study of submarine cables. This division consists of very noted and very competent men. Its principal headquarters are at Toulon, where it was first installed for the laying of the cables from Toulon to Corsica, Sicily and Algeria.

After the report of the English commission, the accidents that occur to cables during immersion were in great part attributed to the circumstance that the ships employed to lay them had not been specially built for this service. In England, the Great Eastern was furnished with special gearing for laying the Atlantic cable, which answered very successfully, but in France the difficulty of getting an appropriate ship for such enterprises has not been overcome.

Vessels destined to lay cables are guided in their destined routes by other vessels, which, being free to move, guide the ship bearing the cable, and, if necessary, render assistance. As the cable is covered with an armor of iron, this great metallic mass acts upon the needle of the compass and disarranges it. For this reason the compass on board the ship containing the cable is not consulted at all, but she depends for the accuracy of her route upon her attendant vessels. The latter are careful not to cross the path of the former, and thus endanger its operations.

CHAPTER VI.

OTHER TELEGRAPHIC SYSTEMS.

THE Morse telegraph, adopted by the International Company, is actually in use in almost all countries. In France this system is generally adopted, except in the case of railways which exclusively employ the dial telegraph, but it is becoming more and more probable that at no distant date even these latter will adopt the apparatus of Morse.

The true inventor of the electric telegraph, he who solved its most important problems, is neither Morse nor M. Breguet, but Mr. Wheatstone. He it was who set up the first telegraph in England, and afterwards one in France, to which country he was invited for that purpose. He it was who invented the first public and practicable telegraphic instrument. He it was who labored continually to work out the various scientific problems in connection with telegraphy, and to reduce them to system and method. He took the chief part in getting up the Blue Book, already referred to. But while the different European governments have paid Mr. Morse a sum of between £16,000 and £17,000 for the right to use his invention, Mr. Wheatstone has

officially received nothing for his works and discoveries.

Morse's machine has been so much improved and altered [mainly by Morse himself, however,] that we may say there is now nothing left of the original machine but the name. Each improver has added his modification and his little discovery. Although the inventors in telegraphy are very numerous, each day is increasing the number. Already there are more than fifty systems proposed, and this number does not include the improvements of systems already in existence. Of the most recent improvements we will notice only the chief.

THE PERFECTED MORSE TELEGRAPH.

Morse's system has been most improved by the talented French mechanicians, MM. Digney, who have introduced into it successively, improvements at once simple and useful. First of all they have effected a change, by means of which the impression of the dispatch given by the receiver is made in ink instead of being merely embossed. To effect this, the lever, moved by the electro-magnet, lifts up the band of paper for a greater or less length of time. The force that raises the lever is hardly appreciable; the weight of the paper itself being of course very slight. When the band is raised it rubs against a wheel that is continually turning. This wheel, covered with a light coating of thick ink, leaves upon the paper marks, greater or less in length, accord-

ing to the duration of the magnetic attraction, but always very well defined and clearly visible. By this means the paper receives the series of points and dashes which constitute the alphabet of Morse's system.

The difficulty which M. Digney had to encounter in accomplishing this, was to regulate the machinery so that the mark should be well defined, and the ink should not spread from the wheel upon the paper. He has succeeded perfectly in his design. The marking wheel is moved by clockwork, in an inverse direction to that in which the paper moves. In its rotation the wheel meets a roll of cloth saturated with very fluid ink. This roll is turned under the gentle friction of the wheel in such a way that the wheel constantly takes from it a minute quantity of ink, just sufficient to leave the mark on the paper. The ink employed preserves its fluidity a long time, and it is only necessary to add a few drops upon the roll every four or five days. The other portion of the machinery of the receiver has not been changed by M. Digney. It is the same machine as Morse's with this advantage, that the dispatch comes away printed, and therefore more easily read.*

M. Digney has, however, modified the manipulator and rendered it automatic. The achievement of this was an important problem, and one which had long puzzled the French administration. So

* This operation requires adjustments so delicate in such a climate as ours that it will hardly be considered an improvement in America.—A.

great indeed had been the number of solutions proposed that the administration at length gave up the subject in despair, and held by the original machine. But after a time they gradually began to make use of the self-acting arrangement of MM. Digney.

A machine is said to be automatic when it passes of itself a dispatch of any kind, presented to it in a prepared form, without there being any need of a clerk constantly occupied in working the manipulator. With such an instrument a single person can transmit and receive at once as many dispatches as there are wires leading into his office, there being no more work for him to do than to superintend the machines and make the necessary preliminary signals.

M. Digney first of all prepared his dispatch with a special machine, called a perforator. By means of this a band of paper is cut into points and dashes, according to the tenor of the message. Two keys acted upon a mechanism which set in motion a steel punch. When one of these keys is depressed the paper passes underneath without any perforation; when the other is pressed down the steel punch cuts into the paper, which then passes on with only a single point cut into it. Two consecutive pressures upon this second key give two points running into each other, or in other words a dash. Thus the composition of the dispatch consisted in acting upon two keys like those of a piano, and the band is perforated as it unrolls. This operation completed, the telegram can be revised—accepted or rejected—before being sent. A recommendation which this process has, is that the employee who com-

poses the dispatch cannot gather the sense of it; he has only to imitate the written model which is given to him.

Thus composed the telegram is taken to the manipulator, and given as it were into the custody of this self-acting machine. The manipulator consists of an elbowed lever, easily movable with the slightest force, and having one of its arms constantly resting upon the perforated paper, which rolls away under it. The battery communicates with the lever, and the line wire communicates with the metallic plate over which the paper rolls. From this it will be seen that if the lever above the paper, and the metallic plate below the paper—the one connected with the pole and the other with the line—come into contact, a current of electricity must pass. When the lever comes down on the paper no current passes, but as the paper moves on, a perforated point or dash comes under the lever, which immediately falls through the open space and touches the metallic plate. The current then passes into the line. The longer the perforation is the longer will the current continue to pass; and the receiver will register a dispatch exactly similar to that which has been put into the automatic manipulator. A simple mechanical arrangement around the elbowed lever guides and regulates its action and the motion of the paper.

The machine operates very rapidly. When operated by a skillful clerk it can transmit 175 letters a minute, while the ordinary system transmits only from seventy to eighty letters. Besides, as there is

no need of touching the manipulator, no risk is run of deranging it. The perforator is substantially made, and writes seven to eight words, of an average of five letters, in a minute.

We may add that the preceding improvements of the two machines are completely independent of each other. The receiver is already adopted everywhere, but the manipulator is yet but very little used.*

MR. HUGHES'S TELEGRAPH.

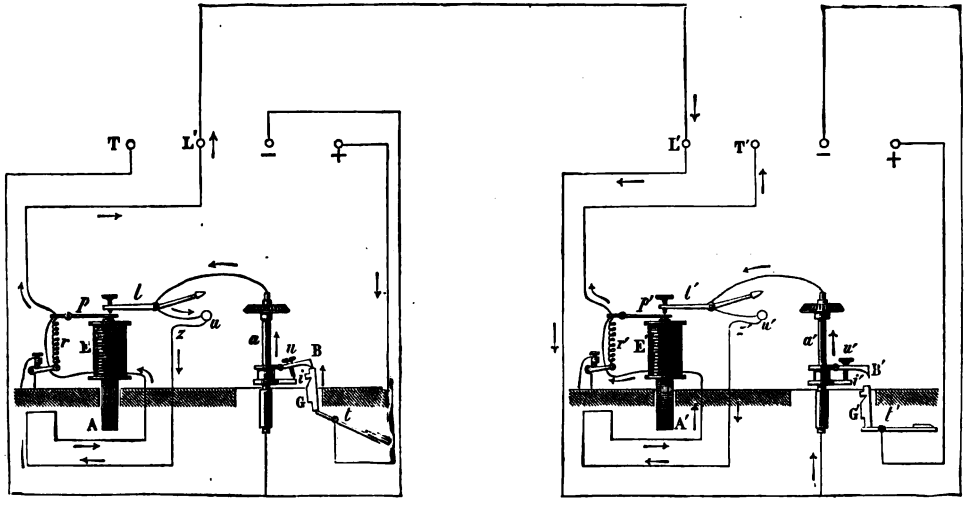
In France, as in England, Mr. Hughes's telegraph is beginning to be employed upon the great lines. This very ingenious but very complicated instrument requires able and intelligent clerks for its manipulation, and cannot be used in branch stations. The peculiarity of Mr. Hughes's method is that it delivers the same printed dispatch simultaneously, both at the place of departure and the place of arrival, which facilitates revision. The working of the instrument is very simple, and though the mechanism is very complicated we shall try to give some idea of it.

When the telegraph is working, the battery, the two poles of which are attached to points marked + and — upon the diagrams, communicates on one side with the earth, T, on the other with a button, *t*. A key-board, composed of twenty-six signs

* Indeed it is easy to see that in the vast majority of messages it can be only an incumbrance. Digney has rather incumbered than improved Morse's system.—A.

or letters, (for the French language,) and two blanks, forms the manipulator. The clerk, in order to render a letter, strikes the corresponding key. The latter is exactly in *t*. It raises a gudgeon marked G, in the sender. The current passes, following the direction of the arrow through all the winding of the wire to the wire L′, which communicates with the receiver.

In its course the current traverses the vertical axis of the manipulator, *a*, moved by powerful clockwork, with great speed. In turning, the axis, *a*, moves a carriage above the twenty-eight holes of a fixed disc, D, as we see in the large illustration. For each sign there is a corresponding hole, and the gudgeon raised by the key, raises in its turn the piece, B, of the carriage. While the battery is not acting, the piece, B, rests by a screw upon the lower part of the carriage; in this case the axis, *a*, which is formed by two conducting portions separated by a small piece of insulating ivory, is connected by a metallic conductor with the earth, T. This piece, B, as we see in the receiver, B,′ communicates with both parts of the axle, *a*, and the current then passing from one to the other, loses itself in the earth, T. In a state of repose, as appears by the diagram of the receiving station, the current traverses the axis, *a*, by means of the screw, *i*, then passes into the ground, T, by a very circuitous route. On the other hand, when the telegraph is working, the piece, B, is raised instantly in passing over the gudgeon corresponding to the letter which has been given; and at that instant, the current



DISPATCHING STATION. RECEIVING STATION.

THEORETICAL DIAGRAM OF HUGHES TELEGRAPH.

which would come from the receiver in the direction opposite to the arrows, would be totally arrested, until the electricity discharged from the battery shall have passed the gudgeon as far as the line wire, L.

After passing through the axle, *a*, the current traverses the electro-magnets, E, of which one commands the receiver of the place of departure, and the other that of the place of reception. In this electro-magnet, the electricity does not act as in common cases. It consists of a strong lower horseshoe magnet. Each pole of this is surrounded by a piece of soft iron, around which the current wire is coiled. When the current is not passing, the soft iron is magnetized by the influence of the horseshoe magnet, and a lever, *p*, is lowered; but as soon as the current passes, the soft iron is partially demagnetized, and the lever, *p*, no longer attracted, yields to the action of an antagonistic spring, *a*, and strikes a screw marked *l*. Thus, at the place where the current magnetizes the iron, and makes it attract its armature in other instruments, here the iron is demagnetized and the armature pulled back by the action of a spring. Only a very feeble force is necessary to effect this last work, since the least weakening of the magnetism suffices to make the spring, *r*, take effect. Naturally the strength of the spring is so regulated that the lever, *p*, shall be in exact equilibrium. The erection of *p* determines that of the lever, *l*, which acts directly upon the receiver.

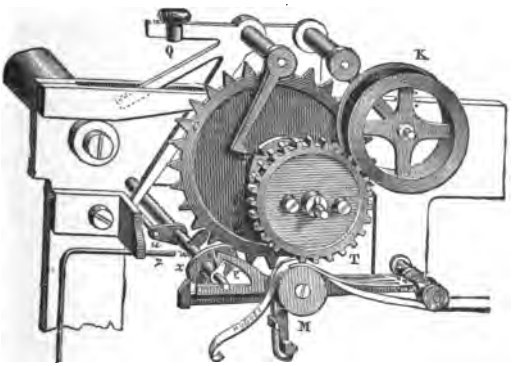
This second part of the apparatus consists of

two arbors near one another, one of which is called the type arbor, because it carries the letter wheel, the other the cam arbor. The latter is formed of two independent parts. The first, invisible in the figure, turns rapidly by means of clockwork, making about seven hundred revolutions in the minute; and it carries a fly-wheel, V, which regulates the motion and prevents all slackening of the motion of the arbor, at the moment when the greatest resistance is presented. In the same way a conic pendulum regulates the movement of the clockwork. The second part of the cam arbor, visible in the following illustration, is independent of the former, and remains immovable, so long as the current does not pass. But as soon as the plate, *p*, has raised the lever, *l*, a catch withdraws from the two parts of the cam arbor, at which they make together one complete turn. This sudden resistance does not slacken the movement of the arbor, on account of the action of the fly-wheel. After making an entire revolution, the catch escapes, and the second part of the arbor becomes again immovable. This second part bears four cams, each of which has a special function.

The type arbor consists also of two portions, one of which turns in a continuous manner with the same swiftness as the arbor of the manipulator, *a*. The other part turns as soon as the telegraph commences to work, and the current has once passed. For this purpose, one of the four preceding cams, the last, *n*, produces the lock between the two parts of the type arbor, and connection once established, it remains all the time the dispatch is passing. To render the two

parts of the type arbor independent, as they ought to be, when no current is traversing the machine, the clerk presses upon the key, Q, and terminates the lock.

Then, as soon as the telegraph begins to work, the type arbor begins of itself to revolve, with the same swiftness as the axle of the manipulator. Two wheels are driven by the "arbor." The one, C, called the correcting wheel, has twenty-eight teeth.



Explanation of the Axes.

Its purpose is to preserve continual accord between the receiver and the manipulator, if in consequence of accidental circumstances the two machines do not run precisely in harmony. The second cam, *u*, engages itself in the teeth of the wheel, C, and makes it advance or recede in such a way that the space shall be precisely in the right position. This cam, *u*, has still another office to perform. When the cam arbor does not turn, it rests upon the spring,

z, which makes the manipulator communicate with the line.

In front of the correcting wheel, and turning with it, the wheel, T, carries the printing characters, which are inked by rubbing against the pad, K. There are twenty-six letters and two blanks—the two blanks corresponding to a wide space. The cylindrical hammer, M, turns under the action of the cam, *x*, which draws onward the unrolling paper; and it is besides raised by the cam, *y*, and striking up against the type-wheel, T, it receives the impression of the letter which is downmost at the instant. We must add that by a mechanism carried by the sender, we can substitute for this wheel of types another wheel indicating the figures and the signs of punctuation as they are indicated by the keys. Such is a description of this very ingenious but evidently very complicated instrument. When the dispatching clerk wishes to address the nearest station, he sets free the clockwork of his machine and presses down a blank key, which rings a bell at the station addressed. As soon as the preliminary signals are exchanged and the two clockwork movements regulated, the correspondence commences. The keys are struck successively and with a rapidity which depends upon the rotation of the axis of the manipulator. When the carriage, B, passes over the raised gudgeon, the current is thrown into the line and the work described above is accomplished. The machines and the clockwork movement are regulated once for all with such an amount of care that the letter printed always corresponds with the lettered key depressed

by the despatching clerk—that is to say, that the gudgeon raised is met by the [illegible] at the moment when the letter of the [illegible] the letter struck on the key-board [illegible].

M. CASELLI'S AUTOGRAPHIC TELEGRAPH.

Among the numerous [illegible] ize an electric telegraph the [illegible] discovered by Ampere, the [illegible] tion of iron—has been applied to the [illegible] graphy already described. [illegible] which has given birth to a very [illegible] galvano-plasty—of which M. [illegible] his autographic telegraph. When an electric current traverses a liquid or a moist substance, the matter of which the liquid or moist body consists is often decomposed and raised to the [illegible] This is the second of the great properties produced from electricity by the voltaic battery.

An English mechanician, Mr. Bain, hit on the expedient of connecting one of the poles of a battery with a piece of iron, and the other with a paper soaked in a particular chemical substance—cyanide of potassium. Every time that the point of iron touched the paper, the current of the battery closed, and at the point of contact a blue tint was seen. The cyanide was decomposed by this simple chemical process, and Prussian blue was formed. The design, of whatever kind it might be, traced by the piece of iron upon the paper, was reproduced in a series of blue points which remained upon the

paper. Such is the principle of Caselli's autographic telegraph.

But from this simple fact of obtaining a blue mark to the construction of a telegraphic machine, a long distance had to be travelled. Numberless difficulties started up to obscure and complicate the problem which the able Caselli proposed to resolve. For ten years he had to pursue arduous studies and make fruitless experiments; for ten years, he chased with avidity an idea that ever seemed to fly from him—a thought that seemed to mock all his efforts. He had to bear the discouraging scoffs of men indifferent to his project, and still more tormenting, remonstrances of friends. He had moreover to endure the sneers of those who proclaimed the end impossible to be attained, and the machine to be impracticable. If, as Buffon says, "genius is only a long patience," we have, in Caselli's case, an instance of this quality which should call forth unusual admiration. At the very outset of his labors he found it necessary to make the marks of the iron traces neat and precise, in order to avoid blotching and spreading of the colors; and this he found was in itself a work of no small difficulty. Caselli achieved this by making the paper sufficiently moist for the chemical reaction to take place, but at the same time dry enough to prevent the decomposition from spreading. This preliminary step accomplished, he next found it necessary to project the electricity into the line, or to arrest it instantaneously, so that in being reproduced, a dot would still be a dot and be always exactly the same size. This also

Caselli successfully accomplished. All the difficulties, in short, that he encountered while his invention was in process, were gradually and successively overcome, always satisfactorily and often by instruments and means of great simplicity. True, he found that the arrangement which would correct one inconvenience would often call another into existence; but each and all he vanquished in detail. We cannot give a complete description of the strange machine and of the multitude of its minute details, each of which has its own particular office to perform. It will suffice here to explain the chief arrangements of Caselli's invention.

A pendulum, six feet long, and terminating in a mass of iron about seventeen pounds in weight, oscillates in a frame. About the middle of the pendulum are two arms, one for the transmitter and one for the receiver. These two parts of the machine are identical, except in small details. Each of the arms connects with the frame, which constitutes the telegraphic apparatus. The frame is immovable, with a surface slightly cylindrical, upon which is fixed the prepared paper. Over this surface an iron needle moves back and forth, horizontally. Every time that the pendulum goes to the right side of the transmitter, the arm drives a lever, which by suitable mechanism moves the iron needle. The latter then oscillates in the frame under the action of the pendulum. It rests upon the prepared paper, when the movement is towards the right; it is raised when the movement is in the opposite direction, and no longer touches the paper. Further, at each os-

cillation the needle advances some little distance in the direction of its length. If, in place of a needle, a pencil sufficiently fine were substituted, there would be traced a series of parallel lines very near each other, but perfectly distinct from one another. The mechanism constructed to accomplish all the motions of the needle is somewhat complicated, but it it is very ingenious. The oscillation of the pendulum, it will thus be seen, determines the back and forward movement of the needle. The latter only touches the paper when it moves in one direction, and at the end of each oscillation it moves so as to mark at a small distance from its former line.

The paper employed in the operation has to undergo a special preparation. For the transmission, the operator makes use of a metallized leaf of paper, which is a good conductor of electricity, and suitably covered with insulating ink. For the reception, a piece of paper impregnated with ferrocyanide of potassium is employed. As soon as the transmitting needle touches the metallic foil the current is thrown into the line, and as soon as the needle meets the ink lines on the foil, the electricity is arrested, but resumes its course when the needle comes again in contact with the foil. At the receiving station the needle is lifted from the prepared paper as soon as the current passes; but when the current of the line is interrupted, a small local current enters the needle, makes it fall, and impresses thus a colored mark upon the paper.

According to this mode of transmission, a despatch written by the Caselli telegraph consists of a

series of very close lines, and upon these lines certain dots are marked. The communication, whether a design or letters, is not made with a continuous line, but with a series of very close dots, giving by their aggregate the same design as the original, in deep blue.

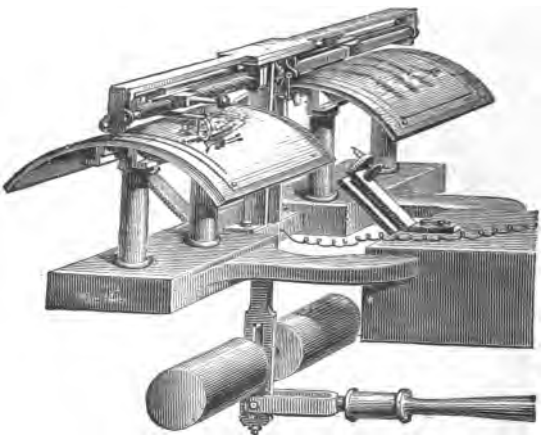
As we have seen, the leaf made use of in receiving the communication, is a leaf of ordinary paper steeped in a solution of ferrocyanide of potassium, not, however, made very moist, and resting upon a

Fac-simile of a Design transmitted by Caselli's Apparatus.

tin support. The current in passing causes a chemical reaction between the water and the oxide of tin which covers the support; this reaction continually cleans the surface of the tin and preserves its conducting power. When the dispatch is finished it appears in deep blue; but if the paper be treated with a mixture of nitric and pyrogallic acids, the design becomes very black and very intense, and it is sometimes under this form that the dispatches are delivered. At other times the paper is treated with an acid decoction of gall nuts, by means of which

a white design is obtained, which is a non-conductor of electricity. This design may evidently be employed as the original design on the plate of tin foil, to send the design to another station.

From what we have said, it will be seen that this machine merely utilizes the motions of a pendulum. The transmitting needle is lowered when the pendu-



Caselli's Transmitter.

lum moves from left to right, and when the latter moves from right to left, it is raised and does not work. It is the same with the receiver. In order therefore that he might not lose half his time and power, M. Caselli made his machine double. By the side of one dispatch he placed a second, upon which a second needle moved in a direction opposite to that of the first. Thus he found he could send two

messages simultaneously without any fear of confusion; because, while one of the needles was in action the other was lifted from the paper and at rest.

One of the sides of the telegraphic pendulum is appropriated to the transmitter, the other to the receiver. They never act at the same time; when one moves, the corresponding arm of the other is detached, which renders it immovable. In the opposite illustration it is the sending branch which is working. Furthermore a bell is moved by the same pendulum when it is required. This bell announces that a message is about to arrive; it is also used to make signals preceding and following a message. As those signals are very limited, Caselli composed a letter vocabulary very easy to understand, and in which a certain number of strokes of the bell have a fixed signification. To set the bell in motion all that is required is a slight pressure upon a key which is invisible in the illustration.

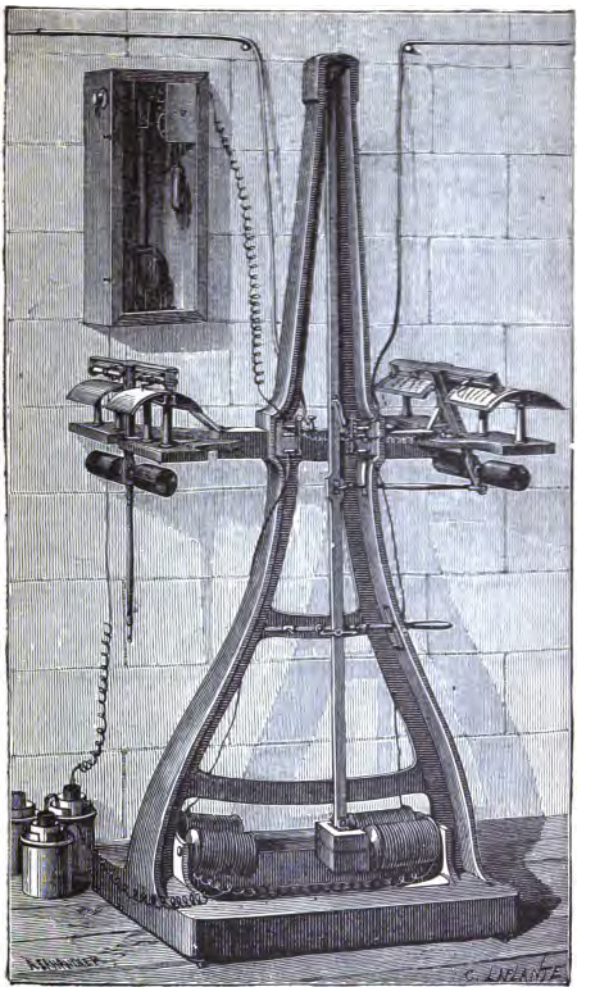
What the inventor found to be his chief difficulty was to make the telegraphic pendulums at the transmitting and receiving stations move simultaneously. He was fully aware that the time of the movement should be exactly the same, and the oscillations should begin and finish at the same time, the smallest disagreement between the pendulums being sufficient to alter the message throughout. Caselli achieved this rigorous exactness by means of a regulating chronometer. At each of the extremities of the sweep of the pendulum is placed an electromagnet, which attracts the mass of iron forming the pendulum weight, and allows it to fall back again,

At certain moments the chronometer throws the current into one of the electro-magnets of the distant station, causing the weight to remain suspended and the pendulum motion to be arrested. Each telegraphic pendulum thus depends upon the regulating chronometer at the distant station. But these chronometers can be rendered as exact as needful by the perfection of their construction. Thus did the inventor bring about the perfect accord of the pendulums of the two stations.

Such are the principles upon which Caselli's pantelegraph is based. Its mechanical contrivances are very ingenious; their details have been carefully planned and combined; and the result is an apparatus truly extraordinary—very ingenious, and thoroughly practicable, though somewhat too subject to derangement.

This telegraph was tried as an experiment for eight months between Paris and Amiens, and it has been worked since the month of August, 1862, upon the line from Paris to Lyons and Marseilles. So satisfactory have been the results that the telegraphic railway line was opened to the public in 1865, which may be said to have been the last and supreme consecration of the discovery. There still, it is true, remain a few things in it to be perfected, but Caselli foresaw and provided for almost everything, so that the alterations necessary to its perfection in practice were found to be unimportant and easily introduced.

The dispatch is written on a sheet of silver paper, with a particular kind of ink. Three lines are



CASELLI'S PANTELEGRAPH.

traced upon the sheet. One serves as a guide for the placing of the needle of the transmitter. The other two are for the guidance of the writer of being necessary to pen a dispatch between the lines as anything beyond the limits of the lines will be untouched by the needle and therefore not transmitted. The sheet of prepared paper is put upon the support and placed under the needle, the necessary signals are given, the pendulum is set in motion, and the dispatch passes to its destination. In this way forty dispatches can be transmitted in an hour, or fifteen words, comprising seventy-five letters per minute, not allowing for any loss of time.

Nor does the marvellousness of the invention cease here. The machine can transmit stenography, and then its rapidity is truly prodigious. At present a plan is being considered for the modification of the apparatus, so as to give it a still more rapid transmission, and to even double its present speed.

The pantelegraph is sufficiently accurate in practice to be made use of even on extraordinary occasions. No special knowledge is demanded on the part of the clerk; on the contrary, his work is merely mechanical. All he has to do is to place the prepared paper, and to watch the movements of the pendulum. The dispatch transmits itself, the machinery being automatic. Results, moreover, are obtained, which at first sight appear to be paradoxical. Autographic messages, for instance, those that transfer even the handwriting of the transmitter, are among the wonders performed by the machine, and are the easiest and most regular of its feats.

As we have seen, also, two different dispatches can be transmitted at the same time. Electricity, by means of these different inventions, becomes one of the most obedient and serviceable forces which man has conquered from nature.

The extreme precision and complication of the mechanism of Caselli's machine does not detract in the slightest degree from its firmness. Its various pieces are not fragile, but the employees must be cautioned not to touch them, because if one of its parts fails exactly to perform its functions, the machine immediately gets out of order.

One defect of the machine may, however, be mentioned, which has its origin not in the system itself, but in the construction of the lines, as they are regulated at the present day. If at the moment when the Caselli telegraph is operating, the line is suddenly traversed by a current other than that sent by the transmitter, it happens that certain dots will not be reproduced, or that dots not belonging to the dispatch will be produced. There frequently supervenes a mixture of wires, that is to say, the wires of one line, from one cause or another, may touch those of another, in which case the current of the one may pass into the other, and produce a certain derangement at the receiver. Or, on the other hand, a thunder-storm suddenly breaks upon the line, and causes accidental currents among the wires. Under these circumstances certain shocks of electricity, not coming from the transmitter, act upon the receiver and make it work.

These inconveniences, it is right to mention, how-

ever, are not peculiar to the pantelegraph of M. Caselli. They equally affect all systems, and they have been modified, if not altogether avoided, by different processes. In the autographic system, such perturbations as we have described have less effect than in other systems. In this system the dispatch forms a regular whole, and as the accidental signals are generally in small number, it is always easy to tell what is regular from what is accidental. Such a fact became evident in one of the first experiments between Paris and Amiens. The testing company were transmitting a portrait of the empress. A sudden interruption took place, and certain signals of the Morse alphabet, which followed another line, were transmitted to the receiver of Caselli. These signals damaged the transmission, and the portrait of the empress was found mixed up with the dashes and points of the Morse alphabet. But no evil result followed. The portrait was sufficiently well known to all, and would have been recognized even under circumstances still more disadvantageous.

Let us hasten to say, however, that these accidents are very rare, and the progress of science has been able almost entirely to avoid them. Thus atmospheric electricity no longer, as formerly, occasions random perturbations, being taken from the line by the ingeniously constructed lightning rod. Indeed, it has been stated that Caselli's invention could work without danger even during a thunderstorm, when the Morse telegraph would be compelled to remain inactive.

It will thus be seen that among the other marvels of telegraphy, we are able by its means to produce fac-similes of surprising accuracy at hundreds of leagues' distance from the spot where the original drawing or writing remains—in other words, to telegraph pictures and handwriting; and artists tell us that the reproductions are sometimes more beautiful than the originals, on account of the softness of the lines, which makes them resemble fine engravings.

THE ACOUSTIC TELEGRAPH.

Wonderful as are these achievements, the inventions in telegraphy have gone still further. To be able to transmit thought to a distance is a triumph which was formerly astonishing; but we are now accustomed to it, and continue to practice it without its creating the slightest wonder. To be able to transmit handwriting, and even drawings, appeared to be more difficult; but this problem has also been resolved, and we now hardly wonder that this feat is accomplished by means so simple. Mankind ever requires a new stimulus to its curiosity, and already it is looking forward to the discovery of more marvels in telegraphy. Some years hence, for all we know, we may be able to transmit the vocal message itself, with the very inflection, tone, and accent of the speaker. Already has the acoustic telegraph been invented; the principle has been discovered, and it only remains to render the invention practicable and useful—a result which, in

these days of science, does not appear [illegible] sible.

Sound, of whatever kind it [illegible] of vibrations, more or less rapid [illegible] from a sonorous body, [illegible] ear. Just as a stone, [illegible] off a succession of [illegible] rings, so a concussion [illegible] analogous vibrations [illegible] it is when these vibrations reach the ear that we become sensible of sound. [illegible] man, M. Helmholtz [illegible] and determined its musical [illegible] him each simple vowel [illegible] notes of the scale, [illegible] notes which are harmonics of these [illegible] strates that it is the union of all these notes that give equality to the voice. Every [illegible] by the notes of the vowel accompanied by [illegible] movements of the organs of the mouth. M. Helmholtz, reflecting upon this, thinks it would be possible to construct a human voice by artificially producing and combining the elementary sounds of which it is composed. This is not the place to discuss such theories, but if we grant that there is any truth in them, we can understand that the acoustic telegraph can be invented and can transmit the living voice. Already experiments have been made in this direction.

A vibrating plate produces a sound, and according to the rapidity of the vibrations, these sounds are sharp or flat. At each of the vibrations the

plate touches a small point placed in front of it, and this contact suffices to throw the current into the line. When the plate ceases to vibrate and returns to its position of equilibrium, it no longer touches the metal point and the current is consequently interrupted. By this means is obtained a series of interruptions, more or less rapid, according to the sound. The current being thrown into the line and interrupted once for each of the vibrations.

At the extremity of the line, the current enters an electro-magnet, which attracts another vibrating plate of size and quality identical with the former. Attracted and repelled very rapidly, exactly, and as rapidly in fact as the plate mentioned above, this second plate gives forth a sound, which will have the same musical value as that of the other, as the number of vibrations per second is the same in both cases.

Should this process be perfected it will be possible to transmit sound by means of the telegraph—to transmit a series of sounds, a tune, or spoken sentence, and conversation. This consummation has not, however, been yet attained. Many experiments have been made, the principle has been applied in diverse ways, and everything makes us hope that we will yet arrive at a perfect system of acoustic telegraphy. Advances have been made very far upon the road to success. A series of vibrating plates, answering to the strings of a harp, has been arranged, each of which vibrates when struck by a particular sound, and sends off electricity to create at the end of a line the same vibra-

tions in a corresponding plate, or, in other words, to reproduce the same sound.

This system, it must be admitted, is at least very ingenious. Experiments have been made in laboratories, that is to say under conditions entirely favorable, and such as we would not often find in actual practice. Under these conditions, a musical air has actually been successfully transmitted by this acoustic telegraph. All must admit that this is a promising beginning; but we must not make too much haste to exalt the miracle and to extol the advantages of the future machine, or to abandon ourselves to the indulgence in indiscriminate laudation on the strength of this new discovery. That would be a gross mistake and an injury to science. True scientific faith is doubt, until the truth appears in uncontrovertible clearness. Care must be taken not to take for reality that which is merely a desire on our part. We must guard against all premature exultation, because it weakens us in the search for truth, and because even one deception is cruel. Let us therefore give to doubt, to patience and to perseverance, the place which some too readily give to congratulation.

THE FUTURE OF THE TELEGRAPH.

Electric telegraphy has already rendered us great service, and we are justified in expecting from it many more benefits. The world is being trans-

formed by means of it; ideas are now exchanged between nations as were formerly their products and their merchandise. Light is spreading—the light of science and knowledge—and the night is gradually disappearing. There will soon be no factitious barriers between nations, and one of the most important agents in achieving this great result will be electricity. No invention is better adapted to satisfy and develop that craving which is natural to man, the enlarging of the boundaries of his knowledge, than the electric telegraph. By its means human action is multiplied, and every one possesses the wonderful power of being, acting and thinking in several places at one and the same time. Thus all the differences of place and character, out of which ignorance had created so many difficulties, are being gradually effaced; thus hatreds and rivalries that spring from imperfect reciprocal knowledge, begin to disappear; thus conflicting interests become common, and will tend hereafter to the same ends—civilization and truth. We are far, very far from having arrived at these last sublime results; but when we think of the powerful impulse given to human effort by the discovery of the electric telegraph, when we perceive that it is not merely private affairs, and the petty occupations of life, but great ideas as well, that are distributed by the telegraph, we cannot fail to have confidence in the future.

Already the whole of Europe is covered with telegraphic wires, which, like the nerves with which the human body is overspread, carry life and movement

to the remotest regions. Already the great governments of both the old and new worlds communicate among themselves. Africa and Asia in their civilized regions are traversed by wires that carry in all directions the burden of knowledge and thought. America is entirely covered with them, and on that continent other projects of a most enterprising kind are being prosecuted with every chance of success. A telegraphic line in the United States is being carried along the northwest coast of America, toward Behring Straits and Siberia. This line will doubtless traverse the immense Russian empire, and on reaching St. Petersburg will connect there with the great European lines. The whole world will thus be girt by an electric line, and Puck's boast become a reality. This Russo-American electric line was to have been finished in 1867, but the delays inseparable from such a gigantic scheme have retarded its completion. When this project is accomplished, dispatches sent east or west, from Paris or from any point of Europe, will arrive in America in a few minutes. An hour, in fact, will hardly intervene before we have an answer from our transatlantic correspondent. This line, or another that may be laid across the Pacific to the southward, will doubtless abolish the monopoly at present possessed by the English and French Atlantic cables, and the sun will shine above some portion of an immense telegraphic girdle every hour out of the twenty-four.

Our fathers invented the telegraph; we have improved it and have accomplished great things by means of it. But much must still be left to our de-

scendants to execute. However simple they may appear, telegraphic machines are in reality very complicated, and their maintenance is very costly. On the one side the price of purchase, and on the other the cost of maintaining them, tend very much to limit the employment of this great reformer. Only governments and large companies can make large and regular use of them, although in England telegraphy has of late years been very much reduced in price, and promises to become immensely more so when the arrangements consequent upon the purchase of the telegraphic lines by the government have all been properly carried out. What at present is chiefly wanted is, that the efforts of practical and scientific men should be directed to reducing their expense. It is necessary not only to perfect this or that little thing, but to discover the telegraph of the future—one that will be simple, easy to work, cheap, and above all things one which will act without a battery. As long as a battery is necessary to a telegraphic machine, the expenses of keeping it up must be enormous, and small purses will be unable to make use of it. Readers must not exclaim that the battery is absolutely indispensable for the production of electricity. A telegraph which does very well without it is already actually in existence—that of M. Siemens—and we shall say a few words further on about this ingenious system. It has been tried, and has given a good account of itself, and therefore the aim we are striving after is not beyond our reach.

In France, the telegraphic lines belong to the

government, with some slight exceptions. Each railway company, for instance, possesses its own telegraph, and the International Company has the control of the frontier lines. The administration of the government lines is in the hands of the Minister of the Interior. Until 1869, the telegraphic lines of England were in the hands of three companies—the Electric, the Magnetic, and the United Kingdom, but in the session of Parliament of that year, a bill was passed, giving the government power to buy up the whole of the lines. This change has since been accomplished, and the new arrangements have shown that the public is greatly the gainer. Great reductions in the price of messages have been made, and the telegraphic system is to be extended to every post-town in the United Kingdom. In America, on the other hand, independent companies possess the telegraphic lines. (See APPENDIX II.)

In October, 1864, France invited the representatives of all nations to a telegraphic conference. Almost all the governments responded; and it was on this occasion that the interior and international tax was rendered uniform, and that precautions were taken for the rapidity and regularity of the service, in such a way that a dispatch could be sent from one country into another without being controlled by the intervening countries. A common alphabet—the Morse—has since then been adopted. In 1862, before the Congress met and reduced the prices of telegrams, an increase of 500,000 messages in ten months was observed, representing an increase of revenue of $31,250.00. Since the Con-

gress the returns have not been published, but the increase must have been very much larger.

A project which originated in France during the discussion in the Corps Législatif, of Caselli's pantelegraph, was rejected at first in France, but was adopted by Spain and Prussia. This was simply a plan of allowing persons to write messages at their own houses upon unstamped paper, either in ordinary language or in telegraphic signs, and send it to the telegraphic office for despatch. This important modification was found to work so well that it is beginning to be introduced into France, there being no doubt that the use of the telegraph has been rendered by this means more general. If the transmission of a message is freed from every sort of hindrance, as we hope to see it, at least under the English government, and as it is in America, and always has been, telegrams will be written as easily as letters, and in fact will, to a considerable extent, supplant them. By this means messages will be multiplied enormously.

CHAPTER VII.

APPLICATIONS OF THE TELEGRAPH.—MISCELLANEOUS APPLICATIONS.

In October, 1867, the French Minister of the Interior was informed of an extraordinary swelling in the waters of the upper Loire and the Allier. The rising continued to increase, and there was danger of inundations near Blois and Tours, where the river banks are very low. Immediately thousands of picks, shovels, etc., were sent to the threatened towns, and the Minister of War dispatched two companies of engineers to direct the works, in addition to two battalions of infantry to assist and maintain order. Protective works were devised and promptly finished, and at the time indicated by the telegraph four days before, the flood reached the threatened towns, and passed by without causing any damage. This is one instance of the important uses to which the telegraph can be applied. Others not less remarkable might easily be cited did space permit.

At Berlin a special system of telegraphy has been arranged for the purpose of protecting the great library against fire. A number of subterranean

wires are led off from the edifice and the dwellings of the conservators to the stations of the firemen. Here there are always about two hundred men, furnished with all the implements necessary for protection against fire, and ready to move at a moment's notice to any part of the building that may be threatened. Besides this, the library is connected by wires with the palace of the Minister of War, where a numerous body of infantry are kept stationed ready to give their help.

Similar systems have been established at Caen and at Bordeaux. Wires connect the Hôtel de Ville with the centre of each quarter, and with the house of the superintendent of firemen. The latter is, moreover, in telegraphic communication with the offices under his orders in the different quarters. Certain conventional signs, transmitted by telegraph, indicate the locality of the fire, its nature and extent, and the number of men it will be necessary to call out. By means of this machinery the necessary assistance can be obtained promptly and without failure.

In Norway, again, where the herring fishery is one of the chief resources of the country, the telegraph is employed in the interest of that great industry. Shoals of herrings come up the fiords and gulfs, and approach close to the banks for the purpose of depositing their spawn. From the moment when this movement begins to take place, the fishing begins. If the fishermen are not apprised of the approach of the shoals they allow innumerable herrings to escape into the open sea, where they

cannot follow them. Hence were frequent disappointments and ruinous losses to individuals and also to the government itself. In this manner a cable of 125 miles in length, and for the most part submarine, has been established. This cable runs along the coast, and communicates with the fishing villages. As soon as a shoal is signalled, the fishermen assemble together and prepare their nets and barrels. They follow the waves which these vast shoals create, and announce far and wide the bay which the herrings have entered in order that all fishermen in the neighborhood may take part in the spoil.

APPLICATIONS TO MILITARY OPERATIONS.

In 1863 Russia introduced a corps of electricians into her army. These were soldiers trained in the service, and in everything connected with electricity, the explosion of mines, the electric light, etc., who follow the army and render a multitude of services. Different bodies of troops, operating in a country, are always, as far as possible, connected with each other by telegraph, so that the general-in-chief can, from his headquarters, transmit his orders, and receive communications which are sometimes of the highest importance. Moreover, the army communicates telegraphically with its base of operations; that is to say, with the towns from which it draws its provisions, arms and ammunition. In no case should an army allow itself to be cut off from its base of operations, for the greatest disasters might

result. Besides a military communication, there must also be a telegraphic one, in order to carry on operations successfully.

It was in the Italian war that the military telegraph was first thoroughly tested, and although the subject was not well studied at first, although a multitude of unforeseen difficulties came up at the very moment when active service was looked for, the results were remarkable, and much more complete than could have been hoped.

Before the arrival of the French army, the Piedmontese and Austrians had each on their side set up an aerial line, of something like the ordinary size, along the highways. The posts were small and light, and it was found that many inconveniences resulted from this line, owing principally to its situation. Upon the roads there was always a crowd of carriages and wagons, infantry and cavalry; the heavy cannon were frequently driven against the posts and the line was destroyed. As soon as the French arrived, they substituted for this line another, of the ordinary height, supported on sufficiently solid posts, and introduced important modifications into the disposition of the wires.

The telegraphic instruments employed in this instance were of the ordinary kind, and were, with the necessary appurtenances, inclosed in a very strong box, easily carried. An arrangement, in fact, was adopted, resembling that which M. Breguet had adopted for his portable railway telegraph. The box inclosing the apparatus was surrounded with straps, and formed a sort of haversack, which

front a sort of chamber, like a travelling carriage. So far have improvements in field telegraphy been carried, that the French military authorities believe that all the difficulties mentioned by M. Lair, in his report upon the telegraphic operations during the Italian campaign, will be diminished if not altogether removed by the establishment, at an early date, of regimental brigades for telegraphic service during war

---

SEMAPHORIC SERVICES.

Occasionally, in France, great departmental networks of wire branch off from lateral lines, the wires of which follow the shores of the sea, and are transformed into cables that stretch out to some neighboring island. Upon dry cliffs and escarped rocks are to be seen a number of small, solitary houses, where these coast lines terminate. Two officials inhabit each of these lonely stations, and employ themselves continually in making observations upon the appearance of the horizon and the sea. These observers transmit the results of their observations to the nearest office with which they are in direct communication, and the latter sends them on to the Minister of Marine, at Paris, who is thus made aware of the state of the weather. On the whole length of the French coast there were, in 1864, 150 electric semaphores, as they are called, but since that time the number has been considerably increased.

Besides the dial machines, and all the apparatus required at a railway station, these semaphore stations include an aerial telegraph. They can thus correspond with the vessels that pass in the open sea, and send or receive from them useful information. These signals do not agree with those of Reynolds, a universal telegraph, adopted by sailors of all nations. The consequence is, that the correspondence is not always easy; but it is hoped that a better arrangement may yet be adopted.

The object of the semaphores is to signal ships which approach, to prevent disasters that might happen to vessels, and to exchange with them valuable information. The signals of the aerial telegraph are visible at a distance of nearly five miles in good weather. By means of these electro-semaphores the steam-packets arriving from Mexico are signalled twenty-four hours before they come into port at St. Nazaire.

Semaphores are also employed in meteorology. They are made use of to give the necessary facts, from which the condition of the weather may be foretold; and they furnish interesting documents for the meteorologic service organized in France.

This semaphoric system, which renders at the present day so great services to the merchant marine, is also very useful for military purposes. The main object of their establishment was to guard the coasts against hostile surprises, and to extend, so to speak, to all the coasts the protection of the great military ports.

ELECTRIC CLOCKS.

The principles of the electric telegraph are employed in regulating the movements of clocks when it is desired to announce the same hour exactly, in several places at once. Upon railways, for example, it is necessary that the hour should be the same at all the stations on the line, in order that all the details of the traffic should be carried on regularly. For this reason electric clocks have been established in France. The clock itself is at the principal station in Paris, and the different pendulums of all the stations are moved by a regulating current in unison with it.

Electric clocks are as various as they are numerous. It is with these clocks as with telegraphs—each inventor has modified some part, overcome some difficulty, and in some way improved the mechanism. All the chronometric systems, however, are based upon the same easily understood principle. A model clock is set up at the head of the line; at each oscillation of the pendulum the circuit closes, and the electricity thrown into the line puts the needle of the distant clock into motion with a jerk. After visiting the first subordinate clock, the electricity passes on to all the others on the line, the time it takes to visit all the clocks on the line being inappreciable. Each pendulum is fitted with machinery more or less complicated, which regulates the passage of the current.

One or more intermediate dials can be passed or omitted at will without excluding those further down the line from the action of the electricity.

Apart from railways, where the electric clocks must be of the greatest importance, a number of towns have had electric dials established to give the same time in different quarters. At Gand, M. Nolet has set up several public, and a great many private electric clocks. All these clocks work very well. A single electric battery supplies the motive power, and the length of the distributing wire is about thirty miles.

Many other towns have followed the example. M. Paul Garnier has, for instance, set up some dials at Paris, Marseilles, Lyons, and some other great towns in the provinces; but, for causes of which we are ignorant, they have been suppressed for some time, and have not been replaced.

When it is necessary always to have exactly the same hour, we can use electricity as a regulator. Thus a company was at one time projected in London, with the object of bringing all the clocks of the different towns to midday at the moment that hour should be declared at the Observatory at Greenwich.

The electric clocks would in that case have worked in a manner independent of each other; but they would have been furnished with electric machinery, and united with the central office of the company. Some minutes before midday electric communication, which is interrupted during the rest of the day, would be established, and automatically precisely at midday, the electric machinery acting upon each clock, the different hands would be brought to 12 o'clock. An arrangement based upon this principle has been adopted at the Grand Hotel, Paris, and in

several other establishments. Each pendulum goes independently during the twenty-four hours; but when midday is registered on the model clock, an electric clock acts upon a regulating machine, and the hands of all the clocks, whether during the day they have gone fast or slow, are brought precisely to midday. By this means, if the pendulums do not go at precisely the same rate, they are never very far wrong, and their divergence gives rise to no inconvenience.

In Paris it is not uncommon to hear the hour of midday sounded for fully half an hour in different parts of the same district. This is an evil which, without changing the clocks, they have sought to correct. Various systems have been proposed; that of M. Vérité, among others, seems to be equally simple and practicable. This inventor places under the pendulum an electro-magnet, into which the pendulum of the electric clock throws a current at each oscillation. The pendulum, covered with a plate of iron, is attracted by the magnet, and tends to remain vertical, and the result of this tendency is a quickening or a retarding of the movement of the balance, according as it is fast or slow, and soon all the clocks are found to go at the same rate. This system has been tried, and has been pronounced excellent; but it was found unsuitable for Paris, the clocks there having pendulums of different lengths. Even should these all beat at the same time, the dials would not indicate the same hour. This, however, is a difficulty which may be overcome.

BOOK SECOND.

INDUCTION MACHINE.

CHAPTER I.

COIL OF RUHMKORFF.

LIGHTNING has not ceased to be regarded as a cause of terror. Man is powerless in presence of this awful force of nature. In vain does he draw assurances from science and from nature, in vain does he take the wisest precautions against these unknown dangers; in spite of himself he trembles. Imagination will not allow itself to be persuaded; a great terror seems to spread itself in the air, and to penetrate all things; memory calls up dismal recollections, and man is humiliated and shorn of his strength by this grandeur, the power of which he cannot control.

But in these days of advanced science we are able, according to our good pleasure, to imitate these terrible phenomena, and repeat them, if not

on a very grand scale, at least in a very startling way. Every evening M. Robin astonished and amused the public by presenting to them actual lightning and actual thunder. Many times, moreover, has M. Jamin, at the Sorbonne, drawn together large audiences to witness the performance of his really magnificent experiments. This, besides bringing spectators and professors together in the most friendly humor, tends to increase our self-possession; for, by proving that we are able at times to command electricity, and by making ourselves familiar with lightning, we acquire the gift of standing before it without trembling.

Moreover, the phenomena of induction, which enable us to imitate in miniature this formidable power of nature, are more than a mere occasion for experiments. Endowed with new properties, transformed, so to speak, in the induction machines, electricity becomes adapted to many admirable practical purposes. Rightly to understand this part of our subject, it is therefore necessary to become acquainted with Ruhmkorff's machine, which is to this day the principal induction machine.

OF INDUCTION.

In consequence of the famous experiment of Œrsted, Ampère set himself to study the action of electric currents on magnets, and also the reciprocal action of the latter upon the former. To begin with, he knew how to deduce from the isolated fact

stantaneously, a current of electricity. Such was the first discovery of the phenomenon of induction. Faraday studied it carefully, and deduced from it all the other phenomena.

Among other things, he found that if the wire traversed by the current, instead of being brought close to the natural wire, were drawn away from it, the result would be the same, and a current would be induced; but if the wires remained lying side by side, without being moved, nothing occurred. The experimenter need not even make the wires move; he need only suddenly throw in the current, or take it away; in consequence of this simple act, the natural wire would continue to be traversed by instantaneous currents of electricity. Finally, it was observed that in bringing near to a natural wire, not a wire traversed by a current, but a magnetized piece of iron, or by removing it, the same effects were produced; the natural wire was traversed for an instant with an electric current. These currents were called *induced currents*, their presence being shown by a galvanometer, or common compass.

Induction of a Wire by a Magnet.

Thus, by a simple mechanical action, making an electrified wire or a magnet move in close proximity to a natural wire, an induced current was produced in the natural wire, of very short duration, but capa-

ble of becoming increasingly energetic, according to the rapidity of the motion of the electrified wire. There was consequently no longer any need of the battery to produce an electric current. Such were the great facts discovered by Faraday; such were the immediate consequences resulting from the phenomena he had studied.

This illustrious electrician did not content himself with discovering these facts. He likewise found out the principal laws affecting them, and discovered almost all that is known about induction. What most struck the philosophers in considering the matter was that a piece of magnetized steel acted exactly like a wire traversed by an electric current. Ampère regarded magnets and currents as identical, and pronounced the extremely bold dictum: "Magnets are bodies traversed continually by electric currents."

Here then are two series of facts, magnetic phenomena and electric phenomena, separated to this day, yet coming together and confounding themselves with one another. We have observed from the first, facts which did not appear to have any connection with each other; we have been beguiled by the similarity of effects to suppose that there was a similarity of causes; but after a deeper study, we have had to renounce our error and Ampère has been able to proclaim this truth, that "one and the same cause may produce effects differing from one another."

Thus science advances; and at every step she detects and destroys an error. At first we accumu-

late facts without discrimination, without order, and as if each of them were due to some special cause; afterwards, in the midst of this medley of things, by the careful study of the old and the new, of the useful and the useless, we see truth gradually disengaging itself from error, and taking form before our eyes. Then everything becomes clear, the facts group themselves in order and take their respective places; and we are able with infinite pleasure to contemplate the sublime simplicity of science.

The great work of our generation is to explain and confirm the discoveries of our fathers. Already, in another department of science, day begins to dawn, the identity of the causes of light and heat has been proclaimed. These two effects, arising out the same cause, acting in a different manner upon organs equally different, were at first also considered separate; but we now consider them as one, and photography has been one of the practical results of that discovery. A day will probably come when we will connect electricity with heat and light, and these three causes being assimilated, will witness by their reunion that man advances more and more in knowledge of the secrets of nature.

The genius of Ampère opened up the way by showing the connection between electricity and magnetism. From this great fact important conclusions have already been deduced. Who can forecast what will be the importance of the complete realization of our hopes? But at whatever distance we may be from this desired goal, we must repeat, and continue to repeat till all are convinced, that it is the-

oretic speculation that leads to great inventions, and that, even when unfruitful in inventions, it enriches science with general truths.

All the applications of induction, for example, result from the theoretic hypothesis of Ampère respecting magnets. Without this hypothesis the phenomena discovered by Faraday would have been unfruitful and would only have embarrassed the study of electricity. A piece of iron is magnetized for a moment by the passage of a swift current of electricity, and this is the principle of the telegraph. A piece of steel, on the contrary, magnetized by an electric current, preserves its magnetization, it becomes a storehouse, so to speak, of electricity, and can afterwards manifest it at any given moment. It becomes a reservoir which seems inexhaustible, and is capable alone, and without a battery, without any apparent generator whatsoever, to produce electric currents. So in a steam-engine, the fly-wheel, which appears at first sight to be the cause of a useless waste of force, is on the contrary a vast reservoir of work, and enables the machine to work regularly, even when the motive power is exhausted. A marked difference is, that while the fly-wheel is exhausted by its action, the magnet only becomes stronger. Here consists the practiccal value of Ampère's idea, and the principle upon which induction machines are constructed.

INDUCTION COIL.

In producing an induced current, a wire is coiled around a wooden cylinder. This wire is covered with silk, in order to insulate th coils, and make the circuit a very long one. Above the first layer of wire, and sometimes simultaneously with it, is rolled a second coil of wire also covered with silk. This forms what is called an induction coil. The wire into which the current is thrown and then interrupted, is called the *inducing* wire; the other, which receives the currents produced, is called the *induced* wire. Each coil of the first acts upon the coils of the second. The current thus produced may be made very strong.

By increasing the number of turns or coils made by the inducing wire, we can considerably increase the force of the induced current. Another very ingenious means for producing the same effect has been found, and that is by placing a bundle of soft iron wire in the hollow interior of the bobbin. Under the influence of the induction current, this soft iron becomes magnetized, and adds its action to that of the current itself, causing the *induced current* to become very much strengthened.

Such are the principles upon which *induction coils*, as these bobbins are called, are constructed. Two wires coiled round a wooden cylinder, and in this cylinder pieces of iron which can be lifted out at will —these form the whole apparatus. Every time that a current is thrown into the first wire, the

second is traversed instantly by an induced current. This current is very strong, and therefore well adapted for certain special purposes.

By the operation described, two induced currents are developed—the one at the beginning, at the moment when we throw the electricity into the first wire; the other at the end, when we withdraw the electricity. We can repeat this series as long and as often as we wish, the currents which result being sufficiently frequent and sufficiently intense to form an interrupted series of electric manifestations. It must be remembered, however, that these currents, developed during one partial experiment, have not altogether the same qualities; they are of opposite kinds.

If we wished here to write a treatise on electricity, it would be a long time before the reader would be familiarized with inverse currents. For some years these have played an important part in telegraphy; and they produce certain very ingenious effects.

The battery possesses two poles, or points where the electricity is accumulated. This electricity is produced in the battery, we do not know how, and the series of phenomena determined by the union of the two poles is attributed to a sort of current of electricity going from one pole to the other. This explanation is purely hypothetical, but it gives a clear and almost complete idea of the phenomena. The battery, in short, may be likened to a double pump, which is a simple figurative comparison. The poles, one characterized by zinc, the other by

copper or carbon, each represents a different machine. The copper pole may be called a force-pump, the electricity generated in the battery, being continually driven out by it into the wire; the zinc pole, on the contrary, may be called an exhausting pump, the electricity from the wire being, as it were, strongly drawn in by it. When the poles are united, the forcing pump constantly sends a flow of electricity from the battery into the wire, which finds itself as constantly drawn into the battery pump at the other extremity. Thus is established the current between the two poles. This supposition is certainly very far from the reality, but in the meantime it is provisionally useful, and we must wait for its rectification till the truth has been discovered.

We admit, then, that the electricity directs itself from the copper to the zinc pole, through the inducing wire, and as a battery is not necessarily made solely with copper or zinc, we have given to these extremities independent names, although they have no signification in themselves. The copper extremity we term the *positive pole*, and the zinc extremity the *negative pole*. If *positive* represent the direction of the *action* of the electric force, and *negative* represent the direction of the *reaction*, the terms will have a more definite and accurate meaning.

In every science we meet in the same way with names applied to certain preconceived ideas, to things incessantly compared. At the beginning, imagination labors upon facts superficially known ·

it creates systems and suppositions to explain what reason does not yet comprehend. Afterwards science advances; facts become more clear each day; errors fall away gradually; the shadows disappear; but very often the terms that have been first employed, though inapplicable, become consecrated by long use; but they embarrass the understanding, and cover our eyes with a sort of veil which conceals the truth from us. We ought therefore to be energetic enough to act independently of our habits and against the tendency to indulgence; we should tear off the bandage, the false transparency of which deforms the true features of objects; and we should learn that the words used and the terms employed are warped from their original meaning. This effort must be exercised with respect to all the names of the science of electricity, such as the words current, poles, positive, induction, etc.

It was, as we have seen, formerly supposed that the current of electricity went from the copper pole, and after following the wire, arrived at the negative zinc pole. But it was found that if by any means we could suddenly invert the extremities of the wire, in such a way that the wire which touched the copper should touch the zinc, the wire would be traversed by a current passing in a contrary direction to that of the former one. This is what is called inversion of the current. This artifice of inversion is employed to produce certain effects. Thus in telegraphy we sometimes connect the wire of the line with the wire of the "earth," and in the experiment of Œrsted we

can, at will, make the magnetized needle move either to the right or the left.

An inducing current which ends, is inverted by a current that begins. In one case the right extremity of the wire induced, represents a forcing pump, while it becomes an exhausting pump in the other case. The functions are in short exchanged; this fact is sufficiently important to call for the preceding remarks.

RUHMKORFF'S COIL.

In 1855 a prize of upwards of 50,000 francs was instituted to reward the savant who should invent the most powerful and useful electric machine; the object being specially to encourage inquiry into the uses of electricity as a motive power. Profound study of the subject soon showed that such uses were at that time a Utopian fantasy that could not be realized, and the commission having charge of the matter generalized the subject, and the prize was offered every five years. In 1860 it was found that no machine answered perfectly to what had been desired, and the prize was not awarded. Even as late as 1865 no new machine had been invented, but in consequence of the importance which the induction coil had assumed, and the numerous uses to which it had been applied, it was judged advisable to award the prize to M. Ruhmkorff. The Commission feared that in showing themselves too diffi-

cult to please, they should discourage students and give the ignorant occasion to say that it was at least strange that during ten years of this century of science, no remarkable electric machine had been discovered.

M. Ruhmkorff accordingly received, in 1865, the prize for the coil which he had invented in 1851—the coil which he had developed and enlarged, and for which he had already been decorated.

From a simple working mechanician, M. Ruhmkorff in time became a manufacturer of apparatus. To his excellent practical qualifications, he added a great love of science, and an admirable curiosity for research. He employed all his time and almost all his resources in studying electricity, discovering here and there little things which other investigators had passed over—giving good advice to all, great and small, who listened to him and thanked him. After having constructed his coil, he rendered it applicable to a multitude of uses, and the sum which was awarded to him could not have fallen into better hands for the interests of science.

His machine is a true induction coil, such as has already been described. Upon a pasteboard cylinder, a coil of very thick wire is rolled. This wire, thick and short, makes only one layer of turns upon the cylinder, and its extremities end at two knobs or buttons, placed upon the support of the machine. This is the induction wire, which is traversed by the current from the battery.

Around this first wire another is rolled which is very fine and very long. In the first machine this

wire had a total length of from five to six miles, but it is now from thirty to forty miles long. This wire makes a very great number of turns around the coil, and ends in two rods. In the second wire, the induction currents are developed, and they are collected on these two rods.

Each of these copper wires is insulated with great care; the second indeed is covered with a coating of shellac. The turns which the wire makes around the cylinder are thus separated from each other, and the electricity is obliged to follow the long route between the two poles. Separation of the spires of the coil is a necessary condition, and negligence of the constructor upon this point would infallibly involve a rupture in the insulation. In order to repair the coil, when from any cause whatever it has become unfit for service, it is divided into smaller portions, none of which communicates except with the one next to it, and when, therefore, the machine becomes deranged, all that is necessary is to find in which portion the fault exists, this being done by trying each one of them separately. The faulty portion is then unrolled and repaired without the mechanician being at the trouble of taking apart the whole machine.

The wires are surrounded with an outside covering of green silk, mainly for appearance sake. The coil terminates in two glass plates, which support it and keep it together. Furthermore, in the hollow centre of the coil is inserted a bundle of soft iron wire, by which the effects of the induction are intensified. Concealed in the wooden base is a peculiar

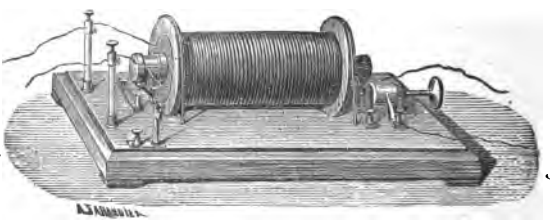
arrangement, called a condenser. It consists of sheets of tin foil, pasted on both sides of [illegible] oiled silk, with an additional strip of [illegible] arranged as to insulate the ends of the [illegible] the whole is folded into several [illegible]

Each of these sheets communicates [illegible] the extremities of the induction [illegible] arrangement the effects are [illegible] condenser of M. Fizeau, the [illegible] which would involve long [illegible] induction coil, somewhat as the [illegible] steam-engine. Its purpose is to [illegible] late the power of the [illegible] keep the inverse currents [illegible]

It is only by an interruption of the voltaic current that we obtain induced currents. It is therefore necessary to interrupt the current from the pile in order that the effects may be [illegible] For the purpose the coil is furnished with a [illegible] called an interrupter, or break-piece, which serves the same purpose as the vibrating armature of the electric alarm. The action of the break-piece is a continual and rapid vibrating motion. It consists [illegible] on one of the extremities of the coil [illegible] in the centre to admit the ends of soft iron wire into the hollow cylinder formed by the inducing coil. These wires rest at the other end on a head of soft iron.

Beneath is a small hammer, the arm of which communicates with one of the extremities of the induction wire, while the anvil which supports it is connected with one of the poles of the battery. So

long as the hammer rests upon the anvil, the current passes into the induction wire, produces the known effects, and among other things magnetizes the core of soft iron wire. The latter being magnetized, attracts the hammer and raises it from the anvil. As soon as the current is interrupted, the iron is demag-

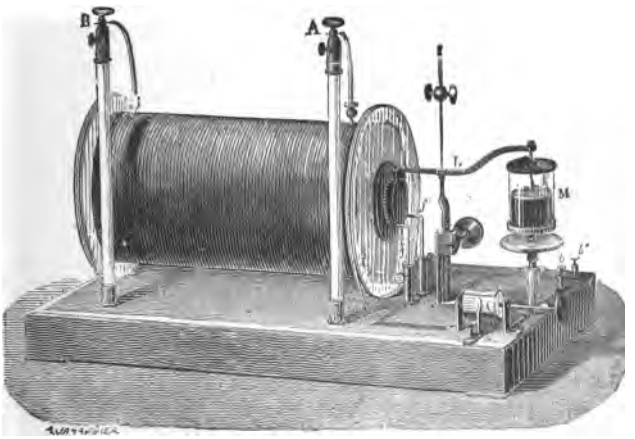


Small Ruhmkorff Coil with a vibrating Interrupter.

netized, the hammer falls back upon the anvil, and the current repasses immediately. This successive action goes on without cessation, and the trembling motion of the hammer becomes very rapid. When it is raised the current stops; when it falls, the current is again sent into the induction wire. If the interruptions succeed each other rapidly, the induced currents will follow at very short intervals, and will give continuous effects.

This vibrating break-piece has this advantage, that it may be regulated at will, by raising or lowering the anvil, thus modifying the rapidity of the motion of the hammer. But in large machines, such as Ruhmkorff now makes, this part of the instrument has disappeared, and has been replaced by a small special contrivance, independent of the rest of the machine. This is an oscillating rod, furnished

with a counterpoise. According as the counterpoise is raised or lowered, the oscillations are more or less rapid. At each oscillation the rod closes the current, and opens it again immediately, and the same effects are obtained from it as with the hammer. Here, however, we must have a special battery



Large Ruhmkorff Coil, with a Counterpoise.

composed of two cups, to move the rod and keep up the vibrations.

The power of the effects obtained, depends on the strength of the induction current, which ought to be regulated accordingly. This current must not be too weak, or only slight action will be obtained; nor must it be too strong, or the undulation will be broken through; for the very fine wire will be burnt or melted, under the action of too strong a current. Generally a Bunsen battery, formed of from fif-

teen to twenty cups, or separate batteries, is attached to the coil, and the current, furnished from this battery, is the inducing current.

EFFECTS OBTAINED.

Ruhmkorff's coil may be considered as used to convert the electricity of the battery into the electricity of the common electrical machine; and we already know the essential differences between these two kinds of electricity. The induced wire is submitted at very closely recurring intervals to the special influence of the current of the battery, and this accomplishes in the interior of the coil a mysterious and invisible work, by means of which ultimately we receive the induced currents instantaneously. A remarkable thing is that the electricity thus produced enjoys at once all the properties of that agent. It presents itself under the form of instantaneous currents like that generated in the battery; it has the energy and the power of the lightning, like that produced from the ordinary electric machine. These induction coils are suitable for a variety of uses.

With Ruhmkorff's apparatus we can reproduce the most extraordinary and the most uncommon effects; exhibiting a spectacle highly fascinating for serious minds. The experiments we are about to describe are well known.

When the extremities of the induced wire are formed of points of platinum, brought near to one

another, a series of vigorous sparks rushes out immediately between the points. Each of these sparks is the evidence of an induced current. If we separate the platinum points, the sparks lengthen in proportion, curving themselves in fantastic windings. They make the air resound with their detonating reports; they follow each other in a long and rapid stream, loud and luminous; and the spectator smells in the vicinity of the machine the sulphurous odor which is perceptible in the air, during great thunder storms, and which is now believed to be the odor characteristic of electricity. There is no deception in this matter. The fire thus produced is actually lightning, and the reverberation, actual thunder, sent forth from machines that are the work of man's hands.

By this process may be obtained in the air sparks of considerable size, striking over a distance of more than a foot. If, again, a long band of gummed paper is sprinkled with copper filings, and this strip, when dried, is placed between the poles, the sparks will play among the grains of metallic powder. At each susceptive particle a small spark will be produced; and as these minute lightnings are very rapid and very close, the eye perceives only a single flash of great length. Thus have been obtained sparks of considerable length, reminding us by their form and their detonations of the lightnings of nature. The only difference consists in this, that the natural lightnings are several leagues in length, while these are only four or five yards; our greatest

efforts fall so far short of the grandeur and the power of nature.

With a coil, as with an electric machine, we can charge condensers, Leyden jars, batteries, etc. But while with the machine we require a very long time to charge a Leyden jar, with the induction coil we require only a fraction of a second, for the production of electricity is immense. We can, even, with certain arrangements easy to be conceived, obtain very rapid discharges from condensers. Then the spark is modified. It is no longer the long, slender, bluish lightning which traverses space, but a short spark, thick, luminous, and creating a loud report. We see a rapid series of large, brilliant sparks, and we hear frequent reports like volleys of firearms.*

---

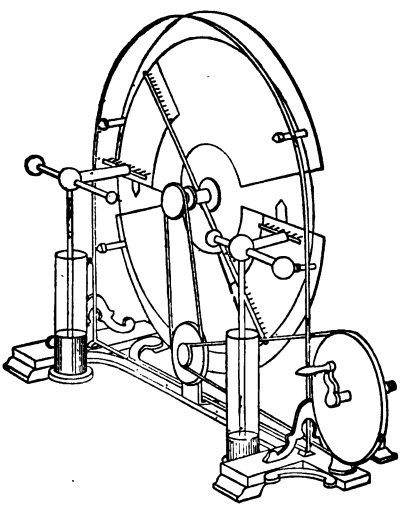
* Mr. E. Ritchie, of Boston, has improved the Ruhmkorff coil in several particulars, tending to make it more powerful, to place it more fully under the control of the operator, and to render its operation less dangerous. In his larger instruments, a jar is charged and discharged so rapidly as to make one loud, continuous, and terrible roar.

The most remarkable electrical instrument invented in modern days is the Holtz Machine, so called from the name of the inventor. This machine is also an induction machine, but entirely different from Ruhmkorff's. In the Holtz machine there are no permanent or electro-magnets employed, and it is independent of galvanic batteries. It consists of a thin, circular glass plate, rotated rapidly by means of a crank and multiplying wheel, very near, and parallel to another, and somewhat larger glass plate. This last plate is fixed. Near the edge it is perforated with two or more holes, (according to the size of plate,) three or four inches in diameter. A pointed strip of card is pasted at each hole, so as to project over about half of its diameter. Both the plates of glass and the cards are coated with lac varnish, to lessen the deposit of moisture. A separate rectangular plate of hard rubber,

Lightning melts metallic wires, bell wires, etc, and the induction spark can also melt and volatize very thin wires. It also marks a black or yellow

about five inches wide and eight inches long, and a cat's skin accompany the machine.

The plate of hard rubber is excited by friction with the cat's skin, and held over one of the holes in the fixed plate while the other is rotating. By this means the rotating plate, without rubbing upon anything but the air in which it rotates, becomes highly electrified, and supplies a vastly greater amount of electricity



The Holtz Electric Machine.

than the friction plate machine of the same diameter. The length of the spark it is capable of giving is from one-third to one-half the diameter of the rotating plate. This electricity is like that of the induction coil. It combines the qualities of both the machine and the battery. So superior is this machine to the late plate

trace, according to whether the wire is of iron, copper, or gold, upon a sheet of paper, placed beneath the wire. This trace is caused by the metallic vapor being violently projected upon the paper, and taking the strangest forms, like those of the richest vegetation. It is thus that bell wires melted by lightning are projected upon the neighboring wall, a blackish line marking the passage of the electricity.

Even the wire of the coil would be melted if we allowed sufficiently powerful currents to be produced. This is a danger which, in the case of telegraphic wires, and especially in that of submarine cables, must be guarded against. In telegraphy we no longer wish to employ direct, but induction currents. We find several advantages in this change; but the danger to the wires, to which we have alluded, is so great as to have made us hitherto consider this difficulty insuperable. In view of this we can now explain the cause of the numerous ruptures of submarine cables; and, among others, that of the transatlantic cable of 1858, which broke a few days after it had been laid. A very strong current, supposed to be necessary from the length of the

---

machine that it is rapidly taking its place, although its cost is greater.

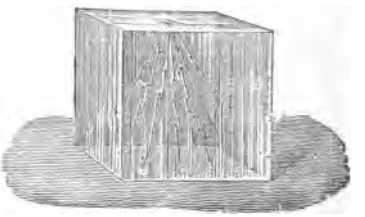
This machine has been greatly modified by the elegant taste and superior constructive ability of Mr. E. S. Ritchie, of Boston. He has lifted it entirely out of the clumsy and awkward position in which Holtz left it, and made it one of the most beautiful of philosophical instruments. The accompanying figure, kindly furnished by Mr. Ritchie, shows the instrument as affected by all the later discoveries.—A.

cable, had been thrown into it. This current created an induction current of equal strength. When the messages were delivered, the induction and direct currents were found going together, the exterior covering forming a condenser, and the whole line being as it were transformed into an immense Leyden jar. Hence the cable immediately began to labor as if in pain; a few words, confused and incoherent, passed along it; and then all was over—the wire had melted, and the insulating covering had broken in several places. The only thing that could have been done would have been to discharge the line, by making the protecting covering communicate for an instant with the wire within. But this plan was not then understood. Since then telegraphists have become prudent, and send along submarine lines only the feeblest currents. The transatlantic cable of 1866 works with a current so feeble that it is only strong enough to deflect a magnetized needle a few seconds.

Induction sparks can kill animals, such as birds; and the strongest machines made by Ruhmkorff are powerful enough to kill a bullock. If a man were struck by one of the discharges of such a machine, the blood corpuscles would be burst, the muscles paralyzed, and the nervous system terribly shaken. If the man were not killed on the spot, he would suffer from such dreadful pains that, as the inventor of the Leyden jar said, the wealth of all France would not tempt a man again to undergo the ordeal. It therefore becomes necessary to handle the Ruhmkorff machine with the greatest

care. Only with a long stick of resin, or glass rod, should the wires be touched or the spark directed.

Natural lightning rends objects, pierces walls, breaks the thickest glass; artificial lightning produces the same effects. If we place a cube of very thick glass between the two points, where the spark emanates, so that the poles will be separated only by the glass, the discharge will explode between the poles, and the glass will be pierced from side to side, in zigzag lines, indicating the course followed by the electricity.



Cube of Glass shivered by Electricity.

Not content with imitating natural lightning, we can obtain new luminous effects, of which nature does not furnish specimens. The lightning that traverses the air has always the same color and character. But if the artificial spark traverses certain mediums, artificially prepared, it will take special and various colors and characters. Glass tubes, for instance, are taken, from which the air has been exhausted, for the purpose of introducing small quantities of different gases. Designs are formed with these glass tubes in the form of letters, animals, etc. Different tubes, some containing hydrogen, in which the spark is red; others, enclosing air, in which the spark is violet, can be combined.

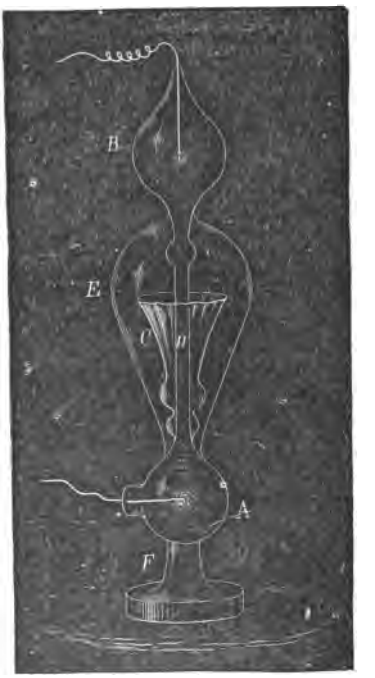
When the spark passes into this series of tubes the designs will appear flaming, and the shining colors will not yield in softness and sweetness to the finest tints.

The ordinary spark is formed by the super-position of two lights. One surrounds the positive pole, and is of an intense red. Coming forth from one of the poles, it stops before touching the negative wire. The other is bluish, less intense, and much shorter than the former. The mixture of these two colors gives the spark a violet tint.

When we carefully examine an induction spark, traversing one of the tubes of which we speak, we see that the blue negative spark is formed by one continuous tint, while the red positive spark, on the contrary, shows stratifications. We distinguish around the positive pole a series of brilliant red bands, separated by obscure bands. These stratifications are transversal, and disappear gradually toward the middle of the spark. The cause of this strange phenomenon is unknown, but it serves to establish a new, singular, and remarkable distinction between the two poles of an electric current.

Not only the jar which fills the tube, but the nature of the glass itself, influences the color of the spark. In these experiments an apparatus is commonly used formed of a vase of yellow glass, called *verre d'urane*, which is inclosed in an egg-shaped vase of ordinary glass. When the spark passes, the yellow vase becomes greenish, a column of fire descends to the bottom of the vase, and from this luminous vase rush forth sheaves of violet rays, as beautiful

as the most lovely flowers. Nothing can limit the variety and power of these effects; and however beautiful, however complicated, be the designs thus formed, the electricity paints itself with colors more rich and intense than those of Rubens.



Uranium Glass Vase.

A further use of the induction spark is to produce explosions; for example, to set fire to a mine, without danger, and with certainty, even when the damp ground would not permit ordinary matches to burn.

In a late expedition to China, a mine was dug underneath the fort of Peiho; powder had been placed in the hollow, and, at the suitable moment, a spark was kindled in the middle of the explosive material by a machine placed at a distance. Immediately the mine was sprung, the fort was blown up, part of it was blown to a distance, the remainder was dis-

mantled by the shock, and the Chinese, who were full of confidence before the event, were frightened into submission.

Loaded cannons can also be fired by electricity, without those who work the pieces being seen by the enemy. Many shots at once can be fired; for example, the whole broadside of a ship, without a man requiring to be on deck. (See APPENDIX I.)

CHAPTER II.

VARIOUS USES.

It is not only because it supplies the means of imitating the lightning that the induction coil is so remarkable and worthy of the reward it has obtained. Apart from this, the great number of uses to which it can be applied combine to make this instrument one of the most valuable and indispensable connected with electrical operations.

Induction currents have at once the properties of lightning and of galvanic currents; and it is to this especially that induction coils owe their practical importance. A single circumstance appears to limit, and, in fact, always does limit, the application of these currents, and that is that of two successive currents, made by opening and closing the circuit, the one is the opposite of the other. There are certain cases in galvano-plasticism, for example, in which it is necessary that electricity should always follow the same route, and in which, therefore, the currents produced by the coil cannot be of any use. It would be necessary, if we wished to apply the induction coils to galvano-plasticism, to allow one

class of currents to pass and to stop the others. A particular machine has been invented for this purpose; but its complication is so great, that experimentalists prefer as a rule not to make use of it. In most cases it is not important that the current should run always in the same direction, and in such instances induction coils can be employed with great advantage.

RAREFIED AIR MACHINES.

In these times of architectural demonstrations it is necessary to work quickly, and especially to rebuild rapidly. Often in passing through the streets of large cities which have been demolished, the observer sees building rapidly going on. A machine lifting stones, the axle turning; the wheels, pulleys, and fly-wheels working as in the ordinary manner; and all this going on in an inexplicable way. Neither furnaces nor steam are to be met with, but the piston is seen acting, the working rods moving as usual; but in vain the spectator seeks for more, and asks himself where is the motive power that works the piston. At first he is wholly perplexed; but after some examination he discovers that the work is being accomplished by the rarefied air machine of M. Lenoir, in which the spark from the induction coil plays a chief part.

Lenoir's invention consists of a hollow cylinder, like the body of a steam-engine; but in place of introducing steam into this cylinder, a mixture of air

and of common illuminating gas is had recourse to. At the two sides of the cylinder are horizontal rods, which regulate the introduction of this mixture. When the piston is raised, the space it leaves vacant beneath is filled with the mixture. The motion of the piston is so arranged as to cause an induction spark to explode, the gas takes fire, burns with a great heat, and the gaseous mixture, suddenly heated, expands with great force. By means of this action the piston is pushed up and a movement is produced. When the piston is raised to the full weight, the heated air from the cavity escapes into the atmosphere, the piston returns back, and the action is repeated indefinitely.

The power of the machine depends on the proportions of the mixture of air and illuminating gas—the more the latter abounds, up to a certain limit, the greater being the heat and consequent force developed by the combustion. Consequently the strength of the machine is not limited altogether by the dimensions of the cylinder. The size chosen is therefore always that which is found to be most convenient. In the common machines engaged for constructing the buildings in Paris, the strength is that of a three horse-power engine—a strength quite sufficient to raise stones and other material to the highest stories of the buildings.

When first invented it seemed as though this machine could only work in the vicinity of gas-works and of pipes, whence the combustible matter could be supplied. But experience has since shown that it can be modified and rendered independent of this

condition, only the expense will be increased. In place of making use of a mixture of air and illuminating gas, it is sufficient to pass the air through a combustible liquid, such as petroleum. While undergoing this process, the air charges itself with combustible vapors, and the electric spark burns these vapors as it does gas. The effect obtained is the same in both cases.

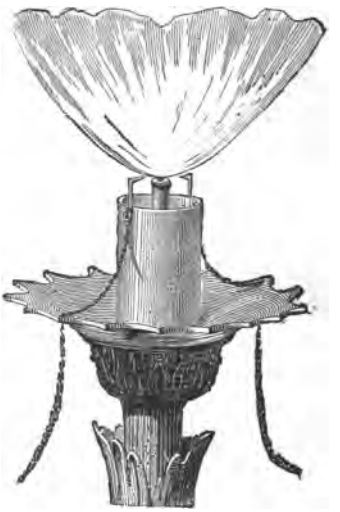
In other respects the Lenoir machine does not differ from an ordinary steam-engine—the motive power alone, and the method of operating it, being new. There being no furnace, the machine can be placed in a small room wherever it may be most convenient.

PUBLIC ILLUMINATION.

Among the experiments which most astonished his audience, M. Robin performed one which he varied in divers manners, and which he most frequently named "The Christmas Tree." Having displayed a pine tree, covered with snow, he caused all the snow to be drawn away by invisible cords, and to be transformed into candles and toys of all sorts, which were of course distributed among the children. So far this was but the trick of an ordinary wizard. But behold! at the order of some one or other in the hall, the candles illuminated or darkened themselves all at the same time, exactly at the word of command. Even in this feat there was nothing extraordinary, though it appeared strange.

The candles were nothing else than gas-burners.

At the word, "light up," a person, visible or not, as the case might be, turned on the gas and threw an induction spark. The latter shone out above all the gas-burners, lighting them up at the same instant—the burners communicating with each other by a metallic conductor. In like manner, at the word "extinguish" the same person turned off the gas, and the burners were extinguished at the same moment, to be relighted in a like manner. Those who listened with attention could hear a small report at the moment when the flame appeared, and could distinguish, also, a pale and violet light, which was the electric spark.



Electric Gas-lighter

It was soon made apparent that this process could be applied to the lighting of theatres, and to the different gas-burners of a public entertainment. It was even proposed to illuminate all the lamps of Paris in this manner, but the idea was not carried out.

At the inauguration of the Boulevard of Prince Eugenie in the French metropolis, a grand triumphal arch was prepared at the entrance of the

thoroughfare. At the moment when the cortege was to pass this arch, numerous gas-burners were to become illuminated all at once, and surround the ornaments of the building with a crown of fire. The rehearsal, so to speak, of the experiment, succeeded admirably, but at the precise moment when success was necessary, and was expected, the electricity remained inactive, and the procession passed unlighted under the vault which seemed all the more gloomy from the splendor expected of it.

The induction spark can serve not only to light gas, but it is capable of becoming sufficiently luminous in itself to be employed in coal mines and submarine works. The question of lighting coal mines interests the whole of humanity. In these subterranean galleries accumulates that terrible gas which is called fire-damp. When it takes fire, fearful explosions destroy the mine, and bury in its depths the numerous workers who go there to earn bread for their families. Every one has heard of the illustrious Sir Humphrey Davy, who has won the everlasting gratitude of miners by his invention of a lamp which in a great degree diminishes the chance of accident. But these dreadful accidents are still continually occurring. Hardly a week passes without our hearing of one in some part of the coal districts. Sometimes these are caused by the imprudence of miners, sometimes by a chance circumstance, sometimes by a blow which breaks the lamp and deprives Davy's invention of its efficacy. Every year, in England, about ten thousand die thus, leaving their families in desolation and misery.

Ruhmkorff, at the suggestion of the director of the mines of Seekreis, in Baden, made an induction machine, to be used as a workman's lamp. Its construction may be thus explained: A very fine tube of glass is bent round spirally, a great number of times, the air is exhausted from the tube, and into it is thrown an induction spark. Within this small space there appears an intensely luminous and regular flame. This luminous spiral is enclosed in a glass cylinder, which protects it, and which the miner carries in his hand. In a box, carried on his shoulders, are placed a small coil battery, and from this box the current is conducted through caoutchouc envelopes to the luminous tube. A metallic reflector, placed behind the spiral, condenses its light.

In this machine the dangers of the common lamp need not be feared. The electric spark is preserved from contact with the air, and if by any cause the tube breaks, the air would enter immediately into the spiral, would interpose itself between the poles, and the spark would at once go out, for the machine is much too weak to throw into the air a spark of an equal length. The apparatus has been tried and pronounced excellent; the light being sufficiently strong to guide the workman and enable him to work; and in spite of its high price, this new lamp is beginning to be employed in coal mines. Moreover as this flame does not require air to support it, it can be used for submarine works, when the worker, furnished with a diving apparatus, is beneath the water of the sea.

SMALL MACHINES.

Ruhmkorff's coil is of considerable dimensions, and its price is often beyond the reach of most purses. Besides, from its great power, it is dangerous to handle, and ought not to be placed in uninstructed hands. Consequently many manufacturers, and Ruhmkorff among the number, have conceived the happy idea of making a small machine, constructed on the same plan, but on a very small scale—a sort of toy which can be carried anywhere, and which is equally suitable for the drawing-room and the laboratory.

Even complete boxes have been made, comprising the coil, the different accessory pieces, and the different luminous tubes, by means of which the curious effects of induction can be exhibited. A thriving trade has sprung up in these scientific toys. Telegraphs, electric machines, Ruhmkorff coils, and all the electric machines discovered by man, after so much labor, are now in the hands of infants, and are used as toys. Nor is this all. There are, it is said, certain ladies, who have demanded from grave and austere science assistance for the toilette, and who have handed over the electrician, in the character of assistant, to their dressmakers and their maids. In the midst of masses of gauze, between the waves of lace and silk, constituting their dresses, have been disposed with infinite art a number of those electric lanterns to which the induction spark can give a sweet and brilliant light. A slender metal wire in such cases passes invisible through the braids of the hair,

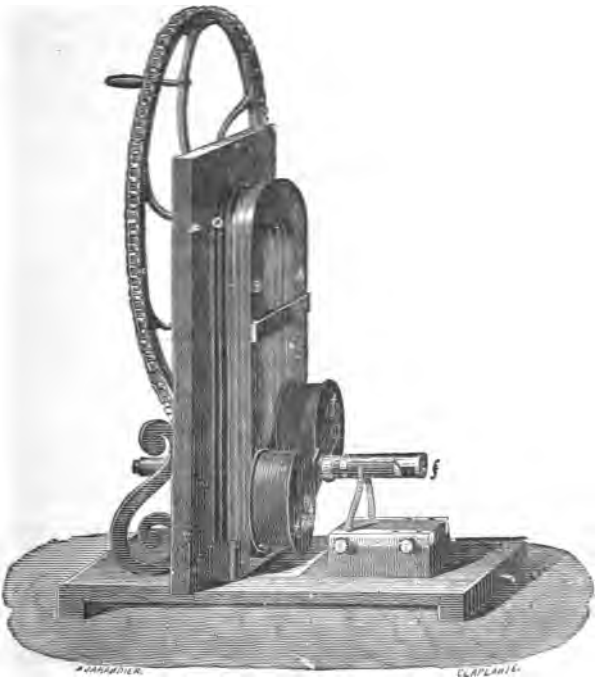
goes along the seams of the dresses, penetrates below the flounces, and finally reaches the small luminous apparatus. Here it is that electricity lends its most varied and delicate colors, while the diamonds and precious stones blaze out on all sides, under the strange light. A small coil with a special battery is concealed in the pocket, and it is only necessary to turn a handle to make a crown of stars immediately shine upon the lady's head.

CLARKE'S MACHINE.

As soon as Faraday had discovered induction, the English sought practically to improve the novelty. Every effort was immediately directed to the curious phenomenon of the production of induction currents by means of movable magnets. It was soon perceived that this new means of engendering electric currents without batteries, was destined to have a great future. M. Pixii constructed one of the first magnets—electric machines in which the electric current was produced by the rotation of a magnet. But this machine, interesting enough to study, from its relation to the history of science, has long ago been abandoned, and has been supplanted by others, more recent and better planned. The machine of which we now make the most frequent use, is that of Mr. Clarke. This inventor only transformed the first machine of Pixii, and made it more perfect.

Clarke's invention may be very briefly described.

A horse shoe magnet, A B, is fixed, and in front of it turns a double coil, *t*, of induction wire coiled around a piece of soft iron. The magnet, which is very powerful, is formed of plates of steel clamped



Clarke's Machine.

together upon a vertical bar. The double coil, consisting of copper wires, is very fine, and is about twenty-five hundred feet long. In the first position each of the pieces of soft iron which forms the mag-

net of each separate part of the coil, is placed in front of one of the poles of the magnet. The soft iron is then magnetized, and it forms the armature of the fixed magnet. This double coil, with the armature, is borne upon an axis, *f*, which can be turned by means of a large external wheel.

When the double coil has made a fourth of a rotation, the soft iron is completely demagnetized, for it is no longer in front of the magnet. Then, in going from the first to the second position, the coil is traversed by a terminating induction current of the same nature as if it had receded from the magnet. When the double coil has made half a rotation the soft iron is remagnetized, and there is produced a *commencing* induction current of the same nature as if the magnet had been approached to the coil. The same result is obtained by the half rotation following, so that at each complete revolution of the axis the coil is traversed by four induction currents, two terminating and two commencing. As the rotation of the axis may be very rapid, the succession of induction currents is rapid in proportion—is, even, so to speak, continuous. Thus the machine is made use of to produce rapidly a series of strong electric currents.

It is necessary, in the first place, to collect the induction currents that are formed. The axis terminates in a metallic collar, which turns with it. This is divided into two parts, each of which connects with one of the extremities of the wire of the coil, and forms the pole of that wire. The collar turns between two plates of brass, forming a sup-

part, and is in connection with them. The induced current developed in the wire of whatever nature it is, passes over the collar, thence upon the plates of brass, and finally upon the pieces of copper forming the foot of the plates, where the currents are received. These pieces of copper are separated by an insulating plate of ivory, and each of them forms a distinct pole of the circuit.

When it is desired to produce electric motion by means of Clark's machine, long spirals of wire are attached to the pieces of copper. The wires terminate in two metal handles, and the person to be operated upon takes one of these in each hand. Care should be taken to wet the fingers in salt water, in order to render them better conductors of electricity. When the patient has the conductors in his hands the wheel is turned. The two hands then become the two poles of the current, and as the body is a conductor the electricity passes through the members and the circuit is complete. But each time that the current passes it causes a shock which may be very strong. This shock or commotion will be all the stronger if the rotation is made more rapid, the coil closer to the fixed magnet, and the induction wire longer and finer. It is in taking note of these conditions that the operator regulates the force of the shock.

With Clarke's machine, all the experiments made with ordinary electric machines and induction coils can be produced. Ether can be set on fire, wires can be made red hot, and even water can be decomposed. When these effects, which are called phy-

sical effects, are sought to be obtained, the coil of fine wire is detached and replaced by another more suitable to this particular purpose. The wire is not long and fine, but thick and short, being only about 130 feet in length. The effects of induction, although less intense, are much more regular and more easy. Besides, as the induction currents are alternately in an inverse direction, and as this circumstance forbids the execution of certain phenomena, such as the analysis of water, care must be taken, in order to obtain these effects, to employ apparatus which makes the currents go one way. This apparatus is fitted to the machine, and is used at the option of the operator.

MAGNETO-ELECTRIC TELEGRAPH.

The greatest difficulty experienced in telegraphy arises out of the necessity of having a battery. This generator of electricity is continually liable to derangement, and is a source of great expense. It is necessary to watch it constantly, it being found most frequently that the disturbances signalled at the station or on the line are due merely to the bad state of the battery. No telegraphic system can therefore be said to be perfect which is not entirely independent of the battery. Formerly, it seemed as difficult to generate electricity without the battery as it still is to produce steam without a furnace. But in our day the induction current has made a

reality of the idea that was considered Utopian, and we see by this that the likeness of electricity to steam is only remote. The following example shows that they are quite unlike.

The currents produced by Clarke's machine are, like all others, suitable to the telegraph; and it was found scarcely necessary to modify this machine in order to make it into a manipulator of the most convenient kind ever known. The magneto-electric system invented by M. Siemens, consists, like all others, in a receiver and a manipulator. It is not our intention to describe these machines here, but we will content ourselves with referring to the improvement which MM. Digney have wrought upon the manipulator, with the view of rendering it able to supplant the Morse manipulator.

The Digney instrument is simply an ordinary Clarke machine, only the coil, in place of making an entire turn around the armature, can only make a quarter of a turn. This double coil is commanded by a lever, which is one in substance with the axis. In lowering the lever the axis turns, in raising it the axis turns the other way, and the coil follows the movements. The lever is stopped at the quarter of its rotation by a catch, and as soon as the catch abandons it a strong spring brings it back to its first position. When the soft iron goes away from the poles of the magnet the coil is traversed by a terminating current; when the soft iron returns opposite the poles, the coil is traversed anew by a commencing current. These currents are thrown into the line, and though they may be in opposite

directions they both act upon the receiver. One of the extremities of the induction wire communicates with the line, the other with the earth. These conditions are exactly those which Morse's receiver demands.

Induction currents being instantaneous, cannot, except in telegraphy, give motion to mechanism. The pencil of the Morse receiver is raised by the first current, caused by pressing down the key, and so long as a second current is not thrown into the wire, the pencil will remain raised and will mark its trace. But if the finger is lifted from the key, at the action of the spring a second current is thrown into the line and lowers the pencil. Here, again, as in the Morse manipulator, the dots and dashes are produced by a lowering of the key for a greater or less length of time.

This machine, simple and easy in its construction as well as in its management, is not in use in France. The administration there is not favorable to the magneto-electric system, and seems to fear that the magnets would not retain their power—a vain fear, for the soft iron forms the armature, and the magnet, continually attracting a piece of iron, cannot lose its attracting power. The administration, moreover, shrinks from the purchase of new instruments, and the loss of all the old material. It is right to add, however, that other countries do not, in general, show much inclination to adopt this system.

M. Siemens was not the first to make use of induction currents in telegraphy. Wheatstone and

M. Steinheil formed each for himself a special system founded upon induction. Wheatstone's machine is employed in England upon private lines. M. Siemens only developed and modified this idea, which he found in science, and he has applied it to all possible systems, with improvements upon the ordinary machines more or less marked. These magneto-electric innovations have brought telegraphy to a great degree of perfection. Experiments made between Paris and Berlin showed that, without intermediate relays, twenty-four words a minute could be transmitted, and the dispatches displayed a neatness which ordinary signals do not attain.

This system has undoubtedly a great future before it. All countries must, it is evident, end by adopting it. If the instruments are dearer than the ordinary Morse machine, the expenses of maintaining and repairing them are almost nothing, and the saving in this respect alone is immense. In adapting the new machines to the existing state of things, the telegraph lines already constructed might serve without any alterations. Moreover, by employing the magnetic system the line would last a longer time; for under the continuous action of a current travelling always in the same direction, the iron wires become brittle and wear; while the induction currents, going alternately in inverse directions, this physical change in the wire cannot be produced.

It is true that grave inconveniences neutralize the advantages thus obtained. To currents of this kind have been attributed a force capable of melting the

wires. But these difficulties that hinder the progress of industrial science will be removed sooner or later—they merely show that its students have ample room for progress.

ELECTRO-MEDICAL MACHINE.

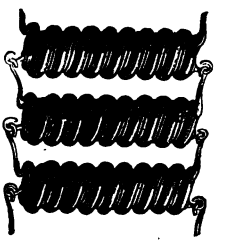
Soon after the study of electricity was begun, it was sought to make use of it for the cure of certain diseases. Long before the invention of the battery, electric tractors, or points, were made use of, by means of which certain men believed themselves to have been cured. There was indeed a time when electricity was regarded as a universal panacea, and people had themselves electrified for all diseases and all afflictions. At the present day, even, inventions of this kind are continually being made public. There are galvanic chains, electric rings, magnetic stays, magnetic belts, cravats, brushes, and shirts, all said to be endowed with wondrous properties and powers. These are but exaggerated pretensions. But though electricity cannot become a universal remedy for disorders, it must not be concluded that it is not effective in some cases for relieving pain, or even curing certain evils. Such in reality is the case. It is specially employed for instance to excite the nervous system. In paralysis, where certain members of the body have become powerless, a strong shock can sometimes arouse the nerves and give them their pristine activity. We have ourselves been witness of a very curious instance. A little

girl was born after a lengthened and painful accouchment, and the organs of respiration would not act. The father, a distinguished doctor, thought this inertia was caused by recent asphyxia. He accordingly electrified the infant, and respiration commenced immediately. Since that time the little girl has grown, and has never felt any difficulty in respiration. It must not be supposed, however, that for all paralyses this method of cure is efficacious. Weakness of the nervous system results from a multitude of causes, and electricity can combat only some of the forms which it assumes. It is not improbable that a shock as sudden, produced by any other means, would be equally efficacious.

When electric currents are sought to be applied as a remedy, the operator must act prudently, examine the temperament of the patient, and judge if the evil resulting from this vigorous cure may not be greater than the disease itself. Especially must the kind of currents which should be employed be discriminated, for all currents have not exactly the same properties. Moreover, the strength ought to be regulated and increased gradually. Generally induction currents are used, because they are so easily regulated.

Sometimes, however, currents from the battery are employed. This is the case when, besides the muscular shock, certain chemical effects upon the blood and the organs are sought to be produced. The battery made use of generally in such cases, is that of Pulvermacher. It is a chain formed of a series of small pieces of wood, upon which two wires

are rolled side by side, and without touching—the one wire being copper, the other zinc. This chain is plunged, for a very short time, in water acidulated with vinegar, and is then drawn out. The wood imbibes the water, and the chemical action of the acid upon the zinc creates a current of electricity. The patient who is to be operated upon takes an extremity of the chain in each hand and receives shocks. The chain was once very popular.



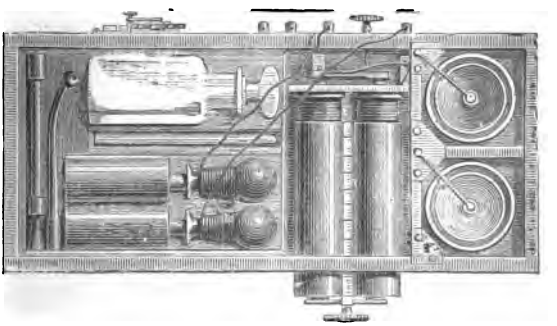
Electric Chain.

Most frequently these chemical effects are not sought after, for the result of such treatment is always very problematical. What is chiefly demanded now-a-days is the production of shocks by means of electricity. For this purpose various machines are made use of. Clarke's machine has many advantages, if we could only regulate it easily when it is in operation. It has been modified many times. M. Page first improved it, and afterwards Dr. Duchesne invented many machines of a similar character, giving either induction or direct currents. But the complicity of these machines limits their use.

At the present time the apparatus most generally made use of is the small induction coil, constructed by Ruhmkorff, and which is a miniature of his great machine. It consists of two coils coupled together. A little battery of sulphate of mercury, composed of two or four elements, throws its current into the induction wire; and the induction current is received

by the two armatures. In order to graduate the apparatus, so that the shocks, at first very weak, may become very strong, we cover the coil with two brass cylinders forming a double movable case. These metallic cases are equally traversed by induced currents which develop the inductor current and neutralize those which they receive. It thus happens that the greater the part of the coil is which is covered by

Pulvermacher's Chain.



Ruhmkorff's Electro-medical Machine.

the brass case, the feebler are the shocks. If the coils be entirely covered, the shocks will be

nothing; if the cylinders are wholly removed, they will be as strong as possible. A graduated rod can be used to draw off the cylinders more or less.

This apparatus is enclosed in a small box, easily carried, and which the doctor may take with him on his visits. When he wishes to use it, he opens the box, sets up the battery with the sulphate of mercury placed in one of the compartments, attaches to the wires the handles he means to employ, closes the box, and the machine works of itself. He has only to regulate the strength. The patient may be cured after a few shocks, or he may be no better. The cure often depends more on the mental state of the patient than on the action of electricity and is therefore very uncertain.

ELECTRIC BATHS.

When it is thought desirable to surround a limb or the entire human body with a sort of electric atmosphere, that each point of the diseased part should receive the same dose of electricity, a bath traversed by an induction current is employed.

The patient places himself in a bath-tub of water slightly saline, and at a convenient temperature. One of his arms is out of the bath, and the hand placed in a basin of saline water. The first conductor of the machine, an induction coil, is placed in this basin, and the second in the bath. As soon as the action commences, the current passes

from the machine into the bath. There it surrounds the entire body, and penetrates to all parts at once; it then follows the arm into the basin and returns to the machine. The body forms part of the circuit, and is generally electrified.

The same arrangements are used for partial baths. Thus each arm is plunged into a basin, and the body

Electric Bath.

being free, the current follows the arms only. In the same way a single arm, a leg, or both legs, can be operated upon, and the application of the agent can be varied as may be necessary.

Since the first electric baths were instituted, a number of physicians have invented new ones.

There is nothing more easy than to throw electricity into water, according to some inventors. The operator has only to make the water enter the circuit of a current of induction, and it is electrified. A doctor who has achieved a certain celebrity—M. Scoutteten—has affirmed that the action of ordinary baths, and especially sulphur baths, is due to electricity, and that mineral waters act upon the organization in the same manner as an induction current. Among physicians, some corroborate, others deny his conclusions, and it is useless here to dwell upon the subject.

Finally, mention ought to be made of a later mode of the physiological action of electricity. A current has the property of making a fine wire red hot; and of doing so all the more quickly in proportion to the strength of the current. When therefore a physician wishes to burn an organ, or a tissue, he sometimes places a thin wire of platinum above the affected part, and directs through it a strong current. The wire reddens instantly, and the tissue is cauterized before the patient has time to cry out or move.

As to the vexatious mania which possesses certain people to explain all things by electricity—it is merely ridiculous. This word serves undoubtedly to designate the cause of certain phenomena; but though the phenomena are known, and can be studied, we are far from knowing the cause. What is the nature of this strange force? How does it act? What is its relation to vital force and all the other forces of nature? We do not yet know; and what may console the ignorant is that before these

questions, the greatest, wisest and most learned, are compelled to stand dumb.*

* The interesting experiments of Helmholtz, in 1866, on the velocity of nervous impressions, appear to settle the fact that nervous influence is not electricity. The motion of electricity through the animal tissues is found to be many thousands of times more rapid than that of nervous impressions. Indeed, railroad cars sometimes move as fast as nervous influence—ninety feet per second.—A

CHAPTER III.

ELECTRIC MOTIVE POWERS.

In this age, in which steam has furnished man with machines so powerful and so various, in which electricity has given him such a rapid means of communication, we are accustomed to believe that all our desires, even the boldest, may be easily realized. Imagination has been excited, and has demanded of science the realization of all her conceptions and hopes. Not content with what has already been done, we now wish to supplant steam by electricity; we wish the latter to move machinery, to draw heavy trains, to execute all sorts of tasks, trifling or herculean; and, as at the first attempt an almost perfect telegraphic machine was invented—as electricity accommodated itself successfully to an endless variety of purposes, people began, in course of time, to believe that it would accommodate itself to one work more, and that we should have electric engines as we have steam engines.

NATURE OF A MOTIVE POWER.

Every force, from the very fact of its producing a movement, may become a motive power; but in its application it is necessary to overcome two kinds of difficulties. It is necessary first that the force should be able to act upon a particular machine, differing according to the nature of the power. This machine set in motion, and its movements applied by various mechanical contrivances, may be used to produce the desired effect. Thus is constructed a water-wheel; a current of water puts it in rotary motion, and it can then, by means of suitably adapted mechanism, turn a grindstone, or the wheels which accomplish the work of the factory. Thus, also, is constructed the piston of a steam-engine. Perpetually pushed by the steam that comes from the boiler, the piston is animated with a reciprocating motion, and continually acts by means of cranks upon the fly-wheel, or on the wheels of the locomotive.

The second difficulty to conquer in establishing a motive power is to adopt means for continually renewing the force. When the water has produced its effect it rolls away from the wheel, and the latter would soon stop if a new quantity of water did not continue the action. When the steam has driven the piston it escapes into the atmosphere, and the movement ceases if the boiler does not generate additional steam. It is thus necessary that the force should be continually reproduced, and that it

should continue to act upon a moving engine in a regular and continuous manner.

Electricity is a force; it magnetizes a piece of iron, and thus causes a movement of the armature. And as we have possessed since the time of Volta a special apparatus in the battery, susceptible of engendering this electricity in a constant manner, and during a certain time, means have been devised for making this agent a motive power, continually renewed, always in the same quantity, and with the same properties. The question to be decided is, can this force not act upon a special machine, put it in motion, and perform a useful work? In order to resolve this we have first of all to seek out a machine capable of receiving the action of electricity, and transmitting the motion, by means of mechanism easy to conceive, to fly-wheels, axles, or railway trains.

It has not been difficult to find a motive power in electricity, and to construct a machine fulfilling the required conditions. Many inventors have come forward, many happy ideas have been realized, and there have resulted from these studies some very ingenious models of electric motive powers. The principle upon which these machines have been founded has always been the magnetization of iron, by means of the current. Magnetized and de-magnetized instantaneously, an electro-magnet constantly attracts and repels its armature; this reciprocating movement communicates itself to different mechanisms, which are to accomplish the work demanded.

Of these different contrivances, the telegraph alone remains a practical success. Here we have a veritable electric motive power, analogous to a water-wheel. But in telegraph contrivances we have constructed all the parts exceedingly mobile, and have made electricity give the signal for action equally and at the same to certain entirely independent mechanisms. This, however, is not the idea generally entertained of a motive power. It is important, nevertheless, to state that although telegraphs may not be suitable to produce powerful effects, the question of electro-motive powers as first laid down, has, for a considerable time, been solved.

Men of science have, however, wished to go further. They have waited to have an actual motive power, suitable to be applied to works demanding great force. Considering that the quantity of coal sunk in the earth is limited, and that there must come a time when it will be exhausted, hopes have from time to time been entertained that coal would become unnecessary, and that electricity would be able to render us the same services as steam. These, however, are hopes which, to the present day, have had no good foundation, and a profound examination of this question has yet to be made.

DESCRIPTION OF ELECTRO-MOTIVE POWER MACHINES.

It is not because machines which have been invented could not probably produce great works and

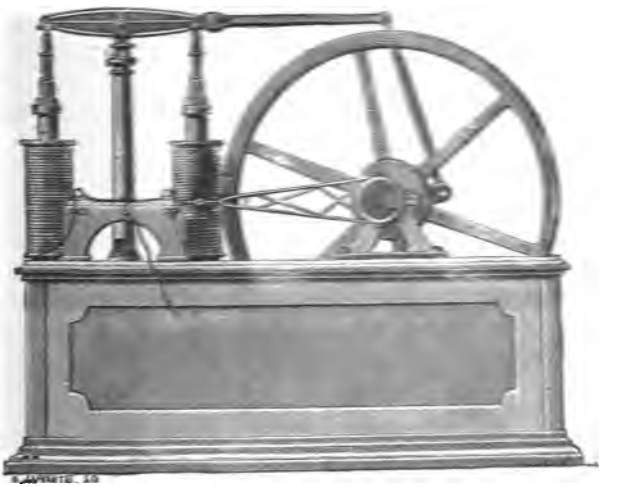
overcome great resistances, that these electric machines have hitherto been failures. We must seek elsewhere for the cause.

We may reduce to three models all the different mechanisms invented to receive the action of the electro-magnet, and to transform the alternating movement into a rotation around an axle.

First of all there has been completed, so to speak, the *vibrator*, such as we employ in telegraphs and induction coils. The rod, raised by the electro-magnet, and falling back by its own elasticity, is animated by a constant oscillating movement. This rod is attached to a connecting rod, which turns an axle and a fly-wheel.

The second model was made first by Mr. Page; but the most remarkable machine founded upon this principle is that which M. Bourbouze constructed for the faculty of sciences at the Sorbonne. Two electro-magnet coils successively attract two pieces of soft iron, and each of these, placed at the extremities of an oscillating beam, lowers itself in turn, and sinks into the interior of the coil. When the current passes on one side, the coil, being magnetized, attracts the soft iron, and the beam lowers itself; when the current passes into the second coil the other extremity of the beam is lowered in its turn. To increase the force the coils are double, and at each extremity of the beam is suspended a sort of fork of soft iron, with parallel prongs. The working-beam, again, is connected with a crank which turns a fly-wheel. The battery is inclosed in the base of the machine. It communicates by

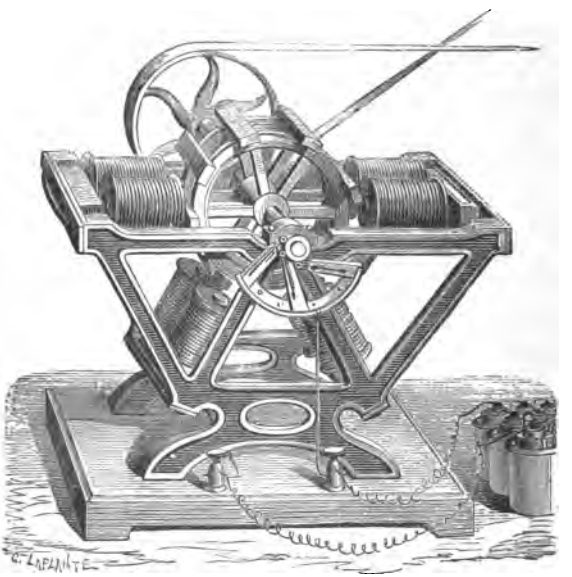
wires with a special piece of [illegible] which is to interrupt the current [illegible] alternately from one side to the other. This arrangement is carried out simply by means of two small bits of iron, separated by a plate of [illegible] a small metallic spring rests upon the iron and [illegible] at the end and at the beginning of its course [illegible] in the first small bit of iron, now in the second and the



Bourbouze's Electro-motive Power Machine.

current is thus thrown from one side to the other. This arrangement of apparatus has been employed by M. Becquerel to measure the force of electricity. The beam is similar to the beam of a pair of scales, upon one of the ends of which weights are placed until the attraction of the magnet and the weight are reduced to equilibrium.

The third model of the electro-magnet is the invention of M. Froment, who was at once a *savant* and a mechanician. The electro-motive power which he has constructed may serve as the type of all machines of the same kind; if ever we employ machines driven by electricity, they will probably



Froment's Electro-motive Power Machine.

be based upon the system of those of M. Froment. A wooden wheel bears regularly arranged upon its surface eight pieces of iron, which serve as armatures. Around this wheel is a frame which supports six couples of fixed electro-magnets. In order to make the above illustration understood,

the upper part of the frame is taken away, and only the four lower electro-magnets are shown.

When the current is thrown into one of these coils, a piece of iron on the wheel is attracted, and has a tendency to descend and to place itself straight upon the face of the magnet. But as soon as the iron has reached this position the current has left the first coil to enter the next one, which draws the piece of iron further on, and each in the same manner, around the wheels. As the six electro-magnets act with a movement tending in the same direction, the wheel turns and the rotation is continued.

It follows, then, than when the piece of iron on the wheel finds itself in front of the electro-magnet, which it lightly passes in consequence of the momentum it has acquired, the current stops and is thrown into the next coil. M. Froment has therefore placed an interrupter upon the axis of rotation, the purpose of which is to draw off the current at the instant required, and to throw it successively into each pair of coils. It never occurs, therefore, that two opposing electro-magnets act at the same time, and it cannot happen that one of the pieces of iron on the wheel shall be attracted at the same time by the electro-magnet which it has just passed, and the electro-magnet which it is just approaching. Were such a thing to happen the wheel would stop.

The wheel moves very easily, and the pieces of iron on the wheel do not touch the ends of the magnets. This electro-motive power has been profoundly studied by M. Froment, and by all the

other men of science who have occupied themselves with the question. It is upon this machine that all the experiments have been made; and as the construction leaves nothing to be desired, its mechanism being perfect, the results achieved require only to be modified in a certain direction to be applied to other machines much less elaborate than this.

The first thing that strikes us when we see a machine of this kind in operation is that the wheel seems able to acquire almost infinite velocity. It turns between its electro-magnets, and we can scarcely see it, so rapid is its motion. But on the other hand, a slight resistance soon stops it, or materially impedes its motion. In an ordinary machine of this kind, the finger alone placed upon the pulley will stop it, and not allow it to turn. In the strongest machines, which M. Froment has made, a greater resistance, though nothing considerable, is required to stop the motion. Electricity, such as we know how to produce, still refuses to adapt itself economically to any mechanical labor.*

* Professor Page, aided by a liberal grant from Congress, experimented largely on this subject, and so successfully, it is said, as to propel a locomotive by electricity, at the rate of eighteen miles an hour. But the cost of the power was many times that of steam. Several experimenters in America have constructed engines of various mechanical capabilities, and of wondrous ingenuity and beauty; but all liable to the fatal objection of great expense in working.

The general disappointment regarding the amount of work an electro-magnetic engine is able to perform, arises from a fact apparently overlooked alike by writers and experimenters, namely, no arrangement yet devised is capable of employing, in *doing work*, more than the one hundredth part of the magnetic force

CONDITIONS OF AN ELECTRIC MOTIVE POWER.

This singular achievement of the wheel of an electro-motive power machine has caused people to study the different parts of the machine with anxious care.

We know that the magnetism produced by a current is strong in proportion to the number of turns made by the wire, and the thickness of the wire itself. We have found by experiments and methodic trials the relation which subsists between the length of the wire and the power of the battery. The thickness of the wire, on the other hand, does not seem to be capable of limitation. Thus the electro-magnets of these machines are made with thick wire, and of a length in proportion to the generating power of the battery. We know, also, that a piece of iron will receive a quantity of mag-

---

actually developed and operating in the engine. To understand this, a w rd on the nature of magnetic attraction will be sufficient. The intensity of this force varies inversely as the squares of the distances between the magnet and the armature. Thus, if a magnet can sustain a weight of 100 pounds, when the armature is one fortieth of an inch from it, on removing the armature forty times as far (one inch) from the magnet, it will sustain only one sixteen-hundredth part as much, or only one ounce. A careful examination of the best instruments constructed will show that the average action of a magnet of the power supposed, will be less than one pound. Until some means can be devised to prevent this loss, the profitable introduction of magnetism as a prime mover is hopeless. If this loss can be prevented, electro-magnetic power will become far cheaper than steam, and therefore universal.—A.

netism, which will be great in proportion as the metal is heavy and thick. Consequently, for movable armatures, that is to say, the pieces of iron on the wooden wheel of Froment's machine, we use sufficiently thick bars of soft iron. If these pieces of iron are too light they will be magnetized immediately, but the surplus power will be lost; if they are too heavy, the wheel will be unnecessarily loaded, and require more force to turn it. There is, moreover, a relation established between the thickness of the iron and the power of the battery.

All the elements and parts of the electro-magnetic machine, however inconsiderable their action, have been thus examined, one by one, in detail and in conjunction. After the French Exposition of 1855, a commission composed of the most eminent men in science and industry, and presided over by Professor Wheatstone, the father of telegraphy, was appointed to investigate this question, and to make known its conclusions. After laborious and extensive comparison and analysis, conducted mostly by M. Becquerel, the problem was presented in the most categorical manner.

It is not the form of the electro-machine, nor the machine in itself that we have to find or improve —what we must alter is the battery which forms the generator of electricity. The actual machines are nearly perfect, and it only remains to produce electricity suitable in quantity and in motive power. For we must fully understand that as we engender it, electricity is in the first place very dear, and in the second place very independent of our will. We

are not sufficiently masters of the conditions in which it is produced, and of the manner in which it acts. It escapes us to perform useless acts, and results follow which we do not desire. We have thus found that it is only the half of the electricity that we get to work for us, the other half is lost.*

OF THE BATTERY.

The battery most frequently employed is that of Bunsen, as being that which furnishes an ample quantity of electricity for a very long time. It consists of a glass vase, V, which is filled with a mixture of water and sulphuric acid. Into this liquid we plunge a cylinder, Z, of amalgamated zinc, the same as in the

Bunsen's Battery.

* However proper it may be to direct attention to improvements in batteries, it is a mistake to think that the mechanism of electro-magnetic machines is perfect. Owing to the construction alone, more than ninety-nine one-hundredths of the magnetic force is lost in the French engine. Professor Henry sustained a ton weight by means of a common copper and zinc battery of less than five square feet surface. Magnets are easily made, which, by a battery of considerable power, would sustain twenty or thirty tons. But applied to such engines, would not have the power of one man. Attention should be directed, therefore, to

batteries which have already been described; then a porous vase, D, full of nitric acid, a corrosive liquid called, sometimes, *aqua fortis;* finally, in the centre a piece of carbon, C, which is at once very hard and very porous, and which is widely employed in electricity, both for the battery and the electric light. The zinc is always the negative pole, and the carbon the positive pole.

The quantity of electricity produced is very considerable, and it is all the more abundant in proportion as the zinc is the more strongly attacked by the sulphuric acid. It has been found out that for electric machines it is necessary, if we wish to work under the best possible conditions, to employ batteries, the porous cups of which are very wide and very thin.

It has been ascertained that to obtain the labor of a one horse-power engine, that is, the labor which the feeblest steam-engine we are in the habit of constructing could accomplish, it is necessary that the battery should consume upwards of four pounds of zinc per hour. A pound of zinc costs, on an average, about sixteen cents. Moreover, as the sulphuric and nitric acids are exhausted they must be renewed, and the expense of the acids alone is estimated at about fifty cents per hour; so that to obtain an electric engine of one horse-power, we

---

the construction of the instrument, rather than to the battery. Nature does not believe in the compatibility of such enormous waste of power as such engines exhibit, and true economy. In this respect Page's engine is far the better.—A.

must expend about eighty cents per hour. On the other hand, with ordinary coal, to set a good, ordinary steam-engine of one horse-power in motion, will cost only about two cents per hour.*

Here, then, is a practical impossibility; the price of electricity is too high. We must alter the battery. But there are two means of doing this. We must first find bodies which, in decomposing, produce electricity, and which will not be any dearer per horse-power than coal. Thus we have attempted various bodies. Iron has been substituted for zinc; it is cheaper, but gives less electricity, and requires more acids. The attempts made, although numerous, have not been satisfactory.

We can, however, try to utilize the immense quantities of sulphate of zinc produced in Bunsen's batteries. Among the reasons why coal sells so cheap is the use that can be made of its ashes; either potash may be extracted from them, or they may be used for manure. But the sulphate of zinc is completely lost; a very small use is made of it in pharmacy, for diseases of the eyes, etc. All the rest is thrown away, or must undergo expensive processes to be made again to take the form of metallic zinc. If we succeeded in finding an industrial use for this substance, if it could be sold easily, at a reasonable price, the transformation of zinc into sulphate would become an economical operation. If,

* In all electric engines yet devised, the expense rises more rapidly in ratio than the increase in power. In the steam-engine it is the reverse.—A.

for example, the sulphate of zinc sold for seventy-five cents per pound, the battery would become a generator of this matter, and the electricity would be obtained almost free of cost. We would then work under the same conditions as the gas makers; from the coal they extract gas, afterwards they sell the coke, the waste of all kinds, and the sale of this refuse is so productive that the gas itself costs almost nothing. How much dearer would the gas be if there was no marketable outlet for the coke? Here, then, is a treasure to be found, a discovery to be turned to account, and also a fortune to be made.

TRANSFORMATION OF FORCES.

We cannot pass by this important branch of our subject without pausing for a few minutes to explain here the principles of the transformation of forces —principles which direct modern science, and in which considerable progress has already been made.

Man is composed of divers organs, and the different forces of nature only reveal themselves in him because they affect his organs and give him special sensations. With our senses we become sensible of as many classes of elementary sensations, differing the one from the other, as we have senses. According as a body affects such or such of our senses and organs, according as it gives us a certain impression, we attribute to it a quality corresponding.

As we have knowledge of ourselves before anything else, we have traced each of our sensations to a particular cause, so that we have introduced into nature as many forces as we have distinct classes of sensations. Formerly, philosophers themselves regarded the luminous properties of the sun as distinct from its heating qualities. They did not consider that if the sun exists at all it is because it produces all its qualities at one and the same time, and that the sensations which our mind recognizes, although caused by external forces, have no existence out of ourselves. It did not occur to them that differences in the mode of acting of the same cause might enable it to influence different organs, and produce different sensations.*

In like manner it is proved that, while large and powerful vibrations of the air shake the whole mass of our bodies, only very rapid vibrations can affect the ear so as to produce sound. Further, our organs are too limited to distinguish all the properties of the sun; and it becomes necessary for us to invent artificial organs in order to recognize all the chemical and phosphorogenic properties of its rays. Photography is only the beautiful practical translation

* At the present day, however, these things are better understood. Although the expressions, "Light, not intense enough to be seen," and "Heat, too intense to warm our bodies," may be used without misleading, it must not be forgotten that heat and light are both *kinds* of motion. If these kinds of motion were identical we would always find the intensity of the heat capable of being measured by the intensity of light, and vice versa. But this is not the fact. The light of the firefly is no index of its heat.—A.

of these discoveries of science, the power which affects daguerreotype plates, is a sort of motion too vivid to be sensible to our retina. A long series of experiments have clearly demonstrated these facts, which we only glance at here.

Mechanical forces, sound, heat and light, chemical action, electricity, and magnetism are then only different manifestations of one and the same general cause, which, variously modified, is able to act upon divers instruments, or mediums, and to produce divers effects. One simple system of forces is spread through space, and regulates all material phenomena. One definitely organized system of forces animates all space, and gives to worlds their motions and their existence. Thus our intelligence can rise to those serene regions from which we may contemplate the eternal laws of nature. They develop before us in their simple and majestic harmony; and man, who has divined and comprehended them, may seek with confidence to attain to what is still unknown.

Electricity is one of the modifications of force; one of the numberless forms under which it reveals itself to us. In its turn it can transform itself and affect our different senses. Now it makes our limbs contract; now, appearing to us in the form of a mechanical force, it carries our messages for us; now it produces sensations of heat or light, and manifests itself by these different effects; now it shakes the air and we hear the reverberation of its explosion, and finally it determines chemical action. All these different effects have been utilized in the arts,

but its power as a mechanical force alone has not yet been practically realized.*

If electricity presents itself under aspects so various, we know how to produce them in a variety of ways. In ordinary batteries we leave the zinc to corrode by sulphuric acid, and this chemical action gives currents used in telegraphy, the electric light, and galvanism. But there are batteries in which heat gives birth to electric currents (thermo-electric batteries;) others in which electricity is only transformed light (electro-chemical-actinometers;) others, finally, in which mechanical force engenders powerful electric effects (induction machines.) From whatever source these currents of electricity come, they are similar, and they present themselves to us with nearly the same properties.

None of the facts which we observe in nature are unconnected with other forces; and none should be regarded as related to only one of the manifestations of force. Divers effects, such as motion, heat, light, chemical action, or electricity, never reveal themselves as isolated forces, or independent of each other. They go together; if in most phenomena one of them is predominant, and conceals the others, it is because our organs are not sufficiently delicate to perceive the more delicate action, but in proportion as science is perfected, machinery, ren-

* But this is not true in such a sense as to make it proper to call muscular contraction, mechanical action, heat, sound, or light, by the name electricity. It would be just as proper to call them all light, or heat, or sound, etc.—A.

dered more sensitive, will become for us actual artificial organs of sense.

APPLICATION OF THESE PRINCIPLES TO ELECTRO-MOTIVE POWER.

We cannot produce one of the effects described without at the same time making others appear. Hardly can we render one of them prominent without causing others to exist along with it; all exist together, and the subsidiary effect takes from the principal effect a portion of its force. Consequently we find that the power we are able to retain for use is always less than the power expended.

Look at a steam-engine and examine carefuly what takes place in the production and application of steam. The combustion of coal is a chemical action which engenders a certain quantity of force. Two effects at least reveal combustion to us, the heat and light of the fire. The light and the other unknown effects are lost to us, and do not in the least assist us in our aim—the production of steam. Heat alone is useful to us; and even that divides itself into several parts. One part, carried away with ashes and smoke, produces no result; the other, and the only useful one, is stored, so to speak, in the water, and transforms a portion of it into steam. Thus in the production of steam we lose a notable portion of the force produced. Nor is this all. In the locomotive the steam acts upon the piston and maintains or accelerates the progress of the trains.

But this is only one of its effects. One portion of the force is used in overcoming the resistance of the air, and the friction of the machinery, and of the wheels upon the rails. This lost portion reappears under the form of the motion given to the air, and under the form of the heat left upon the rails and axles of the carriages. So in the application of the steam alone, we lose a considerable part of the mechanical power it produces. According to the experience of engineers, we only really utilize as mechanical force, in accelerating the movement of the train, three fourths of the force produced by the generation of steam.

It is the same with electricity. When we develop it in a special generator, we do not obtain it alone. The action of sulphuric acid upon the zinc does not give electric currents exclusively. The liquids become heated, the water used is decomposed, partial currents are formed independent of the poles, and these outlets of heat, these accessory decompositions, this production of secondary currents, considerably diminish the amount of electrical force generated. We are not yet entirely masters of the complex conditions and manifold circumstances which accompany the formation of electricity, and which are necessary to it; consequently we are obliged to submit to these losses and these passive resistances.

Moreover, the current which the battery sends into the wire, is weakened by further notable losses occurring in its course. The wire opposes a certain resistance to the passage of this current, the fric-

tion being made sensible by the heating of the wire. This friction is diminished by the selection of thick wires, which are, so to speak, more readily permeable by the current. The electricity does not fill the whole wire at the same time, and the parts which are electrified last are from the beginning submitted to the induction of the parts which have already received the current. There are thus developed in the wire what are called *extra currents*—waves of electrical force, contrary to the principal wave, diminishing considerably its strength. When, by a mysterious transformation, the electricity appears under the form of magnetism—when it begins to attract the armature and cause it to commence the elementary oscillating movement, by approaching the electro-magnet, the phenomena become complicated. The movable armature reacts upon the fixed armature; induced currents run over the wires and the metals, and owing to these complications, the principal current is again weakened. Finally, every time that the current is interrupted in the interests of the work, a small spark is seen rushing out upon the break circuit, between the metallic parts that are separated. This spark is a phenomenon of light and heat, and the electricity occupied in producing these effects is lost for final magnetization.

Such are the principal losses which a current destined to act upon an electro-magnet undergoes. Each of them may be too inconsiderable to be attended to without great inconvenience, but taken together they rob the current of a considerable degree of its power. The effect of these secondary

currents is so pernicious that only one half of the electricity sent into the wire can be employed in the work, the other half being absorbed by the passive resistances. We might easily produce enormous quantities of electricity, but as soon as we attempt to apply it to mechanical work, large portions of it would disappear, and give birth to molecular motion, light, heat, extra currents—things that we do not want, and which are destructive of our purposes. We cannot always force electricity to assume form itself according to our desires, nor can we yet tell in all cases why it affects one form rather than another.

What then are we to conclude? Nothing as yet. The problem has been put, the two difficulties have been set forth, but the solution is waited for. In the actual state of science, an electric motive power such as we hope for is impossible; but it is reasonable to believe that this impossibility is not absolute, and that it will some day disappear.

SOME MACHINES MOVED BY ELECTRICITY.

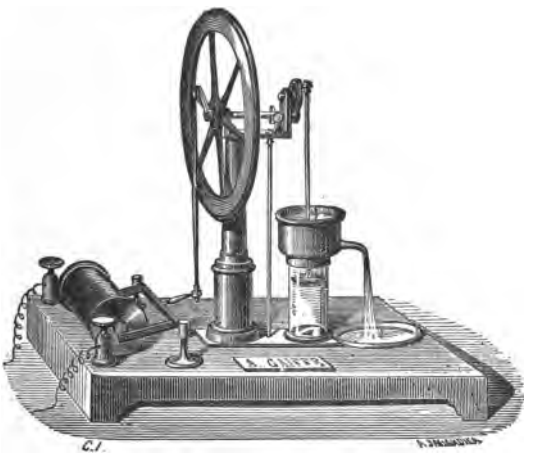
In 1834, M. de Jacobi, an illustrious Russian physicist, constructed the first electro-magnetic motive machine. Afterwards, by order of the Czar, he adapted his machine to a small boat, and made use of electricity to turn paddle-wheels. About 1838 a small boat, containing twelve persons, was able to ascend the Neva, moving for many hours against

wind and current, by means of electricity. This gave rise to immense admiration, and from that time electro-motive powers came into vogue.

This very complicated wheel-work machine served M. de Jacobi as a subject for serious study. It was provided with an enormous battery—128 cells—and the current produced was immense. With such a current, a platinum wire six feet long, and as thick as a piano wire, may be heated to redness instantly. Yet, in spite of its excessive electric force, the machine had only three-quarters of the strength of a one horse-power steam-engine; and Jacobi remained from that time convinced that, in the present state of things, electro-motive powers were impracticable. The battery employed for this experiment was so powerful that the poisonous vapors of the nitric acid rose up from a chimney set up for the purpose quite yellow, and as thick as coal smoke. We may judge from this what this small mechanical force of three-fourths of a horse-power must have cost.

In spite of this well established failure, in spite of the difficulties—theoretical and practical—which render the employment of electricity so disadvantageous, machines were formerly constructed which this force was made to move. We may yet find an advantage in employing this force, and it may happen that its great cost may be compensated for by the use to which it is applied. We may cite as examples, the telegraph and certain toys, the use of which is now wide spread. Thus we often see in the hands of children water pumps moved by electricity. Among this order of inventions may be

classed the magic drum. A drum is suspended in the air; it gives forth sounds, it beats the charge, it executes whatever regimental call is required of it; the sounds follow the word of command, they increase in volume or fall away, and all this without any one going near the drum. It is a little electric current that makes all this noise. Among the wires which suspend the drum is one covered with silk; it



Pump moved by Electricity.

communicates with an electro-magnet placed in the interior of the drum. When the current passes, the electro-magnet attracts its armature, and makes the drumsticks, which are also placed in the interior of the drum, play. On the other hand, when the current ceases, the drumsticks stop. A person concealed from sight hears the orders given; he works or directs the current. In operating the keys he

can obtain any signal he wishes. Electricity is also used for reeling machines in which great force is not required, but swiftness is necessary. The latter is one of the essential qualities of electro-motive power.

But the principal office fulfilled by electricity is to give to mechanism the signal for acting, as it does in the telegraph. Thus a Jacquard loom has been constructed for weaving cloth, in which electricity, arranged for the purpose, when the holes of certain cards present themselves, gives to the threads the signal to lower themselves, or to rise, and thus execute the design. There are many other machines based on this idea, but we shall only refer to the printing machine of M. Gaiffe, which worked at the French Exposition. Its purpose is to engrave the blocks which are used in printing cloth. A small fixed cylinder first receives the design which it is desired to print. A very movable point passes over the cylinder, and continually touches the surface. When a line is marked upon the cylinder there intervenes, between the point and the cylinder, the thickness of the ink which has served to trace the design. This alone suffices to interrupt the electric communication which subsists constantly between the point and the surface. Over the cylinder which it is necessary to engrave, another point, moved by an electro-magnet, passes. When the current no longer passes, the burin or graver, held back by the electro-magnet, yields to the pressure of a spring, and strikes the cylinder forcibly. The spot struck is indented. The movements of the

burin and the point are thus correlative. [illegible] the line formed by the succession of marks, the impression, by a simple mechanical process, is found to be engraved on the cylinder.

BOOK THIRD.

ELECTRIC LIGHT.

CHAPTER I.

THE PRODUCTION OF LIGHT.

If one had said to our fathers, "Behold this intense light which the lightnings flash; see how this glare suddenly increases the horror spread over the whole of nature; these phenomena which affright you will be explained some day, and man will employ them for amusement; he will force the lightning into his service, and cure his diseases; he will render permanent this flashing brightness, and will make this light the rival of the sun." If one had said to the ancients, "This sceptre, with which you have armed the most powerful of your gods, these bolts which he brandishes in his anger will be used one day for the entertainment of man; these unknown instruments which the Cyclops provide for

you by their labors underground, will be ranked among the utensils of the opera," what would these persons have thought who heard such words? Would any of them, even the wisest, have given credit to such prophecies?

And yet, in our time, these prophesies have become realities. From the first discovery of Volta have been deduced successively the different applications of electricity.

It was Sir Humphrey Davy who first produced the electric light. He made use of a battery which comprised not less than 2,000 pairs of plates, and with this enormous quantity of electricity he obtained a jet of light. This new source of light was considered, and when batteries had been improved, it was found that there was no need of such a vast apparatus, and men easily studied and understood it sufficiently to put it to practical use.

OF THE VOLTAIC ARC.

When we bring close together the two poles of a powerful battery a series of very vivid and brilliant sparks pass between the points, when only separated by a very small space. By terminating the wires that form the circuit by two pieces of carbon, these sparks, in place of being interrupted and broken, become so blended as to make one continuous blaze, arching upwards between the charcoal points. This arc of almost constant and very intense light is the Voltaic Arc.

If the carbon points which form the poles were too near—if they touched—the current would be continuous, and the voltaic arc would not be formed. When, on the contrary, these points are separated wider and wider, the luminous arc lengthens and diminishes in brilliancy, until, when the distance has become too great, it is no longer seen. Thus the first condition required for the production of a permanent voltaic arc is to regulate continually with care the distance of the carbon points. But this is not easily done.

Let us attentively examine the voltaic arc; and in order that the dazzling light may not blind us, let us view it through a piece of deep-blue glass. We will thus see how this electric light is composed. To begin with, the carbon is cut into points; the sparks at first rush out feebly and timidly, but very soon the points become heated—they become red hot, and the light is magnificent. We then perceive a great quantity of incandescent solid particles rushing from one of the points to the other. We see the one wearing down rapidly and becoming hollow, while the other increases. This continual movement of the incandescent particles, going from one pole to the other, always marks the redoubling of the brightness of the voltaic arc, and from this phenomenon we are authorized in concluding that this circumstance is necessary to the formation of the arc.

Here it may be noted that the pole which wastes is always the same, always the positive pole, whatever be the battery or arrangement that may be

used. The pole which increases, on the other hand, is always the negative. If we were to employ an illustration we might call the apparatus a double pump—the positive pouring out the carbon, the negative drinking it up.

But it is not only the transportation of the fiery particles that forms the voltaic arc. The carbons themselves become heated white hot.*

Owing to the manner in which we form the electric light, the distance of the poles does not remain constant. During the process the carbons waste, and the distance increases each instant; the light, at first brilliant, fails gradually, and soon goes out if the carbons are not brought near each other again. Every moment, especially when we wish to have a light always equally brilliant, it is necessary to bring the holders nearer, to keep the distance be-

---

* Some of the particles burn in the air as they pass from the positive to the negative pole, thus aiding somewhat the brilliancy of the effects; but the transferred particles and the carbon points, although heated so intensely, suffer very little loss by combustion. The action of the electric forces interferes with and overpowers the chemical affinities of the carbon and the air. This is fully proved by the remarkable fact that the voltaic arc can be formed as readily under water, in a vacuum, in gas of any kind, even such as will not support combustion, in oils and all other non-conducting liquids, as in air; and, in a vacuum, the light is most brilliant of all. As combustion is impossible in many of these cases, it must not be considered as playing any important part in the production of this amazing light and heat. This will help us to understand the important principle, that combustion is only one of the ways in which heat exhibits itself, and that it is an effect rather than a cause of heat.—A.

tween the poles always the same. This is not the only inconvenience.

Not only do the carbons waste away, but the one decreases and recedes, while the other increases and lengthens. The luminous point does not remain fixed; it follows the carbon which increases; it shines out or pales with it, and, after a certain time, the illuminating rays have neither the same origin nor direction as at first. This serious inconvenience would have considerably limited the employment of electric lights, for, in most cases, we make almost an absolute necessity of the fixity of the luminous point. But the difficulty has been overcome. Instruments have been invented which are called regulators, to regulate the electric light, and to supply it with the qualities in which it was wanting.

PHOTO-ELECTRIC REGULATORS.

This apparatus supports the carbons and regulates their distance every moment. There are many varieties of this contrivance, but they all rest upon the principle of making use of the electricity itself to regulate the motion of the carbons. This happy idea is due to M. Foucault, of the Observatory, at Paris, whose death has made such a blank in the world of science; and innumerable constructors of regulators have borrowed his idea to apply it to their inventions.

A photo-electric regulator ought to fulfill three

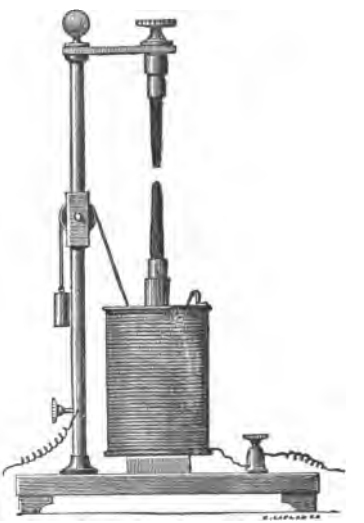
conditions. First of all it is necessary that the light should be constant and uniform, avoiding those rapid variations from great light to twilight, which fatigue the eyes and ruin the sight of those that work at the light. It is necessary, further, that the light reflected in a certain direction should not change that direction, therefore the luminous point should be strictly immovable. Finally, it is necessary that we should be able at will to adjust the luminous point—raise it or lower it, direct it upon one point or upon another, as we do with an ordinary lamp—without extinguishing it. These conditions are indispensable, and every regulator that does not fulfill them should be rejected.

There is no necessity to describe all the instruments devised for this purpose; nor indeed wo ld it be possible on account of their complexity and variety; but we must at least revert to the more important.

As soon as M. Foucault had indicated the true solution of regulators, learned men and mechanicians set themselves to work, and in a very short time there was invented a long series of machines. Of all the methods set forth, one was unanimously considered superior to the others, that of M. J. Dubosq, an accomplished Parisian mechanician. Its qualities were at once recognized, and it was adopted in the greater number of the experiments to which the electric light was applied.

In order to show clearly how the current itself may serve to regulate the distances of the carbon, we shall describe a very simple and very imperfect

machine, which has never yet come into general use—namely, that of M. Archereau. In this machine the current coming from one of the poles of the battery stops at the upper carbon, which is supported by a fixed, horizontal arm; the lower carbon is fixed in a movable support, formed of a piece of soft iron. The current coming from the other pole passes into an electro-magnet, and goes from that to the lower carbon.—As soon as the carbons are made to approach each other, the light flashes forth; but the current, in passing into the electro-magnet, magnetizes the coil, and the soft iron is attracted. It descends, drawing with it the lower carbon; so that by the effect of the electricity the carbons are separated, and the light is weakened. But in proportion as the distance between the carbons increases, the current diminishes more and more in intensity, and the magnetization of the electro-magnet becomes less and less strong. The soft iron, the supporter of the lower carbon, by means of a counterpoise, carefully adjusted, tends to rise. There is thus estab-



M. Archereau's Regulator.

lished an equilibrium between the action of the counterpoise and that of the electricity, and the equilibrium maintains the two carbons always at the same distance from each other. From this description it will be seen how we can regulate the distance of the carbons by electricity itself. This is only one of the numerous processes which have been published and applied. The process has been perfected, and we only give it here as a very simple example of what may be done.

The two machines most in use are those of M. Dubosq, of which special use is made in experiments in physics, theatrical effects, etc., and that of M. Serrin, which has been constructed principally with a view to being used in electric light-houses. M. Serrin invented the recoil system, the advantages of which no one before him had even suspected. When the carbons arrive at the centre, at the fixed point which ought constantly to be the middle of the luminous arc, an automatic mechanism makes them recoil. It is in this that M. Serrin's chief invention consists.

After some years, M. Foucault invented a second instrument. All possible excellences and desirable conditions seemed to be united in this, but it is very complicated. The arc is constant, the luminous point regulates itself easily, and the machine does not become deranged. If by any means, such as the breaking of the carbon, the arc becomes extinguished, the carbon springs up suddenly, without any one being employed in watching the luminous point, and the arc relights itself immediately. The

mechanism is so firm that we can incline and even invert the apparatus without altering the light—which makes it peculiarly adapted to the lighting of vessels. In order to obtain those advantages, however, a complex mechanism was necessary. But after all what does it matter? It is only the constructor who has a right to complain, for, as he who manages this apparatus has only a handle to turn, he can easily ignore vanquished difficulties of the construction. As for him who wishes to understand them, he must put himself to a little trouble.

THE CARBON POINTS.

The regulator makes the length of the voltaic arc constant, and the light ought always to have the same intensity. But in reality this last condition is far from being fulfilled, and for this we must blame not the machine itself, but the carbons. The conductors of electricity might be formed of two carbon crayons, light and very pure, but then the combustion would be very quick, the carbons would disappear almost immediately; to replace them, much time would be required and the expense would be considerably augmented. Consequently it is necesry to choose a very hard and very dense carbon, and one which is at the same time combustible. We take that which is called retort carbon.

When we distill coal in order to procure gas for illumination, there remains in the retorts, first the

coke and afterwards a peculiar kind of carbon called retort carbon. The latter is formed in thick, black metallic layers, very hard and very difficult to cut; it lines the top of the retort, the part which has been least heated during the distillation. This is the material which has been selected for all electrical purposes. Like all carbons it is a good conductor of electricity; further, it is porous—a quality which has caused it to be employed in the Bunsen battery to replace the copper; finally, it is very dense and very combustible, which makes it sought after for electric light.

Long pointed pencils or rods of this carbon are cut, which serve as conductors. These are fitted to the regulator, and the carbon points become the poles of the battery; the regulator brings them near to each other, and it is between the points of the carbons that the voltaic arc is formed. As the brilliancy of this arc is due at once to the passing of heated particles, and to the incandescence of the carbon points, anything which retards these processes will enfeeble the electric light.

But retort carbon is far from being pure; it contains small grains of sand within its mass, in considerable numbers. When one of these grains of sand occurs in the glowing point of the carbon it cannot burn, it does not conduct electricity well, it does not become incandescent, but requires a great quantity of heat to melt it, and it rolls from the top point to the bottom, as we see in the illustration, the electric light during all this time being weakened. This is the cause of the disagreeable flickerings of the

appears that the processes of its manufacture were both difficult and costly. This chemist could have obtained his carbons at this pitch of perfection only in very small quantities, which proved, of course, a great disadvantage. Plumbago was also tried, that is to say, natural carbon, which is almost as pure as the diamond, and of which we find rich mines in several countries. Experiments with this were made at the Opera, but without good result; perhaps because the plumbago scaled off too easily, and was a worse conductor.

When it is considered that the quality of the electric light depends chiefly upon the carbon employed, we need not be astonished that the attempts to perfect this kind of light have been neither very numerous nor very successful. With respect to improving the electric light, a backwardness is to be observed, which we do not see respecting other difficulties connected with electricity.

THE MAGNETO-ELECTRIC MACHINE.

Generally, to obtain electric light, we make use of a Bunsen's battery of from forty to fifty cells connected together as a series; the current formed, passes to the regulator, and thence to the carbons. The luminous point can, like some kinds of lamps, be surrounded by glass globes, transparent or dim, according to the effect desired to be produced. When an operator wishes to make use of the elec-

tric light, in circumstances that do not vary, he employs a magneto-electric machine to produce the current. He avoids the costly and disagreeable manipulation of batteries, and renders the production of the electric light an economical process, because, in using this machine, lightning costs less than lighting with oil.

We have only to reverse the question of electric motors. To transform the electricity into a mechanical force is a problem we cannot solve economically under present circumstances, but the transformation of mechanical force into electricity is as easy as it is economical. By Clarke's machine, for example, in turning a wheel more or less quickly, we create in a coil a series of induction currents, which we can collect and utilize for various purposes. Mechanical labor, as developed by the rotation of the wheel, becomes, by the aid of the machine, an electric labor. It is upon the principle of the Clarke machine that the apparatus of which we are about to speak is constructed.

Instead of consisting of only one fixed magnet, the magneto-electric machine contains no less than fifty-six, distributed upon an immovable frame. This frame contains a series of seven octagonal grooves. Eight very strong magnets are arranged in a vertical plane, with their poles towards the centre, one magnet upon each side of the octagon, and the frame is composed of seven such planes, side by side. Within the groups of magnets are the armatures and coils. They are formed of soft iron, surrounded by copper wire, covered with silk.

These armatures are double. When at rest, each soft iron places itself before one of the poles of the magnet, and forms its armature. All these coils are supported upon one movable axle.

When the axle turns, each coil approaching or receding from a pole of a fixed magnet, is traversed by an induction current, which is very powerful, because it is instantaneous. All these partial currents, developed in each of the 112 coils, are united in a single one, of which the power is enormous, for one can easily understand that, with care and attention, we can coil the wires upon the armature, and attach them to one another in such a way, that all the currents shall have the same direction, and consequently, that they will strengthen each other. The current resulting from the whole, is carried to the carbons and produces the voltaic arc. The coils turn very quickly, the induced currents follow at exceedingly short intervals, and the light is maintained constantly.

The quicker the revolution of the axle and the coils it carries, the quicker the induced currents are developed, and the shorter these currents are, the stronger they are. All the conditions are mutually dependent. It is perceived, in short, that up to a certain limit, the intensity of the light is directly in proportion to the swiftness of the rotation; but when the axle makes 350 or 400 revolutions per minute, the light ceases to increase and remains stationary. Two hundred currents per second are thus produced, and the eye is unable to perceive any quivering or interruption of the electric light.

The currents move alternately in contrary directions. The passage of the incandescent particles of carbon being sometimes in one direction and sometimes in another. The result is that the two carbons are consumed equally, because the waste by transference is equal in each. Now it may happen that for certain purposes we may require to employ currents moving always in the same direction. We then attach to the machine a very complicated apparatus, the purpose of which is to separate the currents: sending back those of one kind, and admitting only those of the other into the circuit. Or again, we use another machine, also very complicated, to alter the course of the currents that do not run in the direction desired.

The intensity of the current is immense. With a current giving the maximum of strength, we obtain a light equal to that of about 90,000 candles, so great is the quantity of electricity developed. This fact will enable the reader to estimate the strength of the current. In making it pass through a very fine platinum wire, the wire becomes red hot, and sometimes melts; but it is easy to measure the heat produced, and to find out from that the intensity of the electricity disengaged.

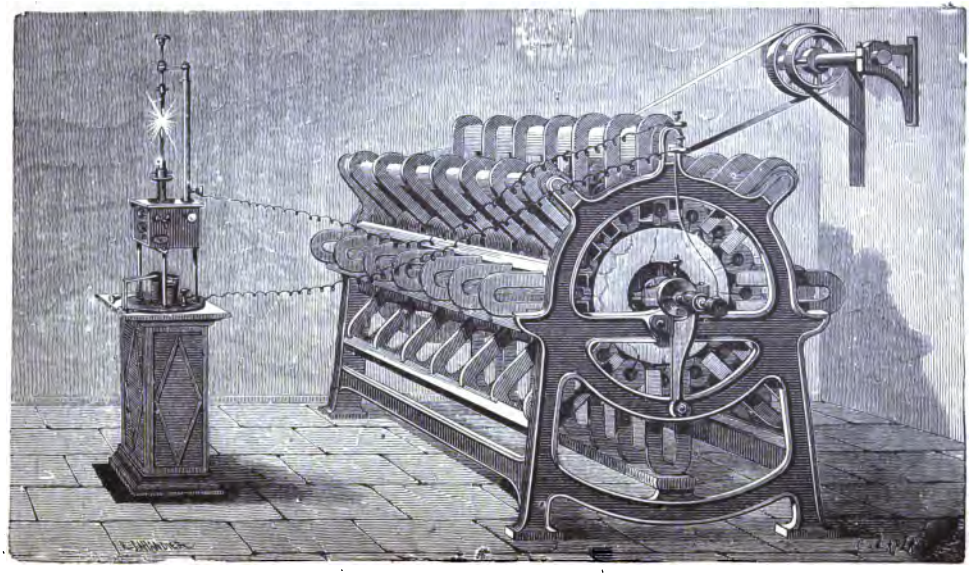
The coil is set in motion upon its axle by means of a small steam-engine. A machine of two horse-power is more than sufficient to turn this axle, which is not restrained by any friction, or any passive resistance. In factories, however, where steam-engines are already in operation, this new work can be performed by them, and they can be

made to turn the wheel of the magneto-electric machine, without its being necessary to strengthen or transform them. The light thus obtained costs only the price of the carbon, that is to say, about two cents per hour; though it is necessary to estimate also the cost of the instrument, and some expense of maintenance, which naturally increase the price of the electric light.

This machine has been constructed by what is called the Alliance Company, which has been formed for some years, with the object of improving and constructing magneto-electric machines. Thanks to this company, and to the experiments and the work of all kinds undertaken by it, the electric light has at the present day become very popular. This first result accomplished, it is pursuing other aims which, it is to be hoped, it will also attain. The French Government favors these experiments, and the company has been enabled to establish its factories in the vast courts that surround the Hôtel des Invalides. A certain number of skilled men of science, and of savants, have attached themselves to the company, in order to study the phenomena, so complex and so interesting, which such powerful currents present.

LIGHTHOUSES.

Every evening the sea-coasts are illuminated, and, as it were, girt around with a cordon of fire. The ships that pass in the open sea are



THE ALLIANCE COMPANY'S MAGNETO-ELECTRIC MACHINE.

guided by these signals, know their exact position, and can steer whichever course may be desired. Perhaps no country in Europe, or in the world, rivals France in the regularity of this service; certainly none present a system of lighthouses so complete. French lighthouses are classed in four categories. Those of the first order, fourteen marine leagues apart, indicate localities, and serve as a guide to vessels which do not approach the coasts; the second and the third order indicate the bays, reefs, and roads; and those of the fourth order are placed at the mouths of rivers and entrances to ports. Each of the lighthouses, ranged along the coasts, is distinguished by a series of special signals, so that a ship passing at sea, perceiving signals, immediately recognizes the lighthouses and knows its true position. These signals are of various kinds.

The lighthouses, with fixed lights radiating all around them, send their light in all directions and always with the same intensity. Efforts have been made to color the light, in order to have a greater number of signals—and thus establish lighthouses with lights of red or green, or with lights colored red or green alternately; but these colors, it was found, could not be depended upon, on account of the disturbances of the air, which would change entirely the colors as seen from a distance.

Revolving lights are the most common. The light emanating from the lighthouse lamp is concentric, with eight rays, and these rays are made to turn around the horizon. A ship at first sees a bright light, then the light is extinguished; soon

after the light shines again, to be extinguished immediately afterwards. The rapidity with which these signals succeed each other forms the distinctive sign of the lighthouse.

Up to about the commencement of this century, curved mirrors were used for reflecting the rays in a particular direction. These mirrors rotated with a uniform movement. Fresnel, one of those to whom modern science owes most, substituted for these, section lenses, formed of a series of concentric lenticular zones. These lenses possess the property of concentrating all the rays along the horizon in a certain direction. They are of very delicate construction, but they render immense service to the lighthouse department. By means of them, the range of the light is much more considerable than with the mirrors, and the light is clearer and more constant. Above the flame is disposed a conical hat-like arrangement, formed of glass prisms, which disperse the light in the same direction as the lenses.

In revolving lights, the lantern is formed of an octagonal drum, of which each face is an annular lens, such as has been described, and surmounted by prisms that make use of the rays that rise upwards. This lantern revolves upon its centre, and the direction in which the light is sent, turns with the drum, thus forming alternate eclipses and illuminations. If the drum makes one revolution per minute, the lighthouse presents eight illuminations and eight eclipses in the same time; and this is its distinctive signal. If the drum does not turn, the

lens is constructed under the form of a true cylinder, and the lighthouse is ranked in the class of fixed lights. In the illumination of lighthouses, people for a long time made use of actual fires, the source of light being a fire of fagots which was carefully maintained. About the year 1700 a French savant replaced these fires by oil lamps, and since then, these latter have been vastly improved. At the present day, lamps with a double current of air are made use of, the oil being pushed up the wick by means of a small pump, worked by clockwork, and the excess falling back into a vase, which is thus always kept full. If the oil does not come in excess to the wick, the vase becomes empty, and in consequence of this diminution of its weight, it draws attention to the fact by sounding a signal bell. Above the wick is a glass chimney, and there is an arrangement for regulating the draught. Detailed instructions are given to the keepers respecting their duties and the management of the lights. The wick of the lamp is formed according to the scientific conclusions of Arago and Fresnel, by four cylindrical concentric wicks, which yield the most intense lights. From these are obtained a maximum light of four thousand ordinary gas jets, or a light equivalent to twenty-four thousand candles. By management of the wick, this immense light is concentrated at the centre of the lens.

An ordinary lighthouse of the first rank has a range of from eighteen to twenty miles with the intensity indicated; it consumes about twenty-five ounces of oil per hour, and costs about fifteen hun-

dred dollars a year for maintenance. It is attended to by three keepers. The price of the accessory apparatus, without including the lantern, is sixty-two hundred dollars. For many years the electric light has been tried for lighthouses, and a careful comparison has been made between the old and the new systems. At Havre there exist two lighthouses situated at the Cap de la Héve, distant about three hundred and twenty-five feet from each other. They indicate the entrances to the port, and the mouth of the Seine. They were reconstructed lately, and it was on that occasion that the comparisons spoken of were made. The lighting apparatus in the electric lighthouse of the Héve is enclosed in the upper lantern, while at the bottom of the tower are placed the magneto-electric machines and the steam engines that work them.

A detailed and very interesting report was made on the occasion by M. Reynaud, director of the lighthouse department. He found that the substitution of the electric light for the light produced by the rapeseed oil possessed no advantage respecting the length of range; but it was of great advantage on account of its intensity. Thus an oil lamp, of which the intensity was equal to twenty-three Carcel burners, or one hundred and eighty-four candles, could be replaced in a lantern of the same force by an electric lamp, equal to one hundred and twenty-five Carcel burners, or one thousand candles, only the range of the light was not sensibly increased.

It must be remarked, however, observes M. Reynaud, that the intensity being greater, the light will

more easily traverse the atmosphere when it is charged with fogs and mists. Moreover, prudence demands that we should at least have two magneto-electric machines, so that there should be two sets of all the apparatus necessary to the lighthouse service, whether the lights be ordinary or electric.

Thus, our informant adds, when the weather is foggy, one would be able to work the two machines at the same lamp, and thus double the intensity of light. This change in intensity would not cause much inconvenience, because the distinctive characters of lighthouses consist not in their difference of range but in the duration of their eclipse. It may, however, be asked with propriety whether, in all cases, the keepers would be the proper persons to judge when the double machines should be used.

M. Reynaud points out another advantage which is not to be disregarded. In foggy weather the steam-engines could be employed to set in motion powerful sounding instruments, and to substitute at such a time acoustic signals for luminous ones. After a time this subject was examined, and at the London Exhibition was displayed a special steam whistle, newly invented and already adopted in some lighthouses. For some years bells have been used at certain seasons, but these methods are but of little use, as their sound reaches but a short distance.

It must be borne in mind, moreover, that the regularity of electric lighthouses is far from being equal to that of the ordinary ones. A carbon may break in the middle of the night, and a long time may be required to fit in another. The position of the luminous point

moreover is not absolutely fixed; the voltaic arc being very short, the divergence of the light is very small; and in consequence the thickness of the ray is very little; finally the present optical machines, such as lanterns, lenses etc., cannot be made use of on account of the shortness of the arc.

Also it does not appear that the ordinary lighthouses could be changed into electric ones. There are besides considerations of economy to be taken into account both as to the expense of purchase of the optical apparatus and the cost of the light. An electric light, for instance, of 125 Carcel lamp power, like that of la Hève, costs one cent per jet per hour, comprising the expense of maintaining the machine and the interest of the original cost of the apparatus; whereas with oil of rapeseed the burner costs four cents. On the other hand the accessory expenses of electric lights are greater; the keepers of the light are not capable of repairing breakages or of acting in cases of urgency.

The electric light, or rather the induction spark, was applied for the first time to light buoys in England. These buoys or floats are a peculiar kind of cask, firmly anchored in a particular spot, the special duty of which is to warn vessels that there is a sandbank or sunken rock beneath. For instance, in the sea between two neighboring lighthouses there are places dangerous to navigate. In such places buoys are anchored. During the day they are always visible and their presence shows the danger; but when darkness comes they have to resort to signals to make their presence known. Some carry on their top a

mirror which reflects the light from the nearest light-house; others are furnished with sounding apparatus, which is set in motion by the waves when a storm rises. Others, again, carry two conductors of electricity, and the sparks passing between the two wires, make the buoy visible, a cable laid at the bottom of the sea, and connected with a small house on shore, being employed to carry the electric current to the conductors on the buoys.

CHAPTER II

APPLICATIONS OF THE ELECTRIC LIGHT—COLORATION OF THE VOLTAIC ARC.

THE light of the electric arc is, as we have seen, produced at once by the passage of incandescent particles, and by the intense ignition of the carbons. A great heat prevails in the midst of this source of light. If a wire of iron is introduced between the carbons, the metal melts at once, then burns rapidly, and throws out on all sides a multitude of sparks, like a shower of stars in fireworks. Metals, even the most refractory, such as silver, gold, and platinum, taken in small quantities, are melted and volatilized by the action of this flame.

On the property of the arc a number of very curious and scientific experiments have been made. For instance the operator cuts the lower carbon, or positive pole, into the form of a small cup, and places in the hollow small fragments of metals, upon which the electric action is thus concentrated. Immediately the metals melt, and are soon reduced to vapor; the particles themselves are repelled from the lower carbon and found sprinkled over the upper carbon.

Among other experiments, the electric light has been colored. The particular tint of the flame is due to the nature of the incandescent particles passing along the voltaic arc. Subjected to a great heat these particles radiate differently colored light, as yellow, white, blue, or red, according to the nature of the substance. If the flame is formed of pure carbon, like that of the voltaic arc, the color will be white, as white as that of the sun; if, on the other hand, the flame contain common salt, like all the flames in common use, such as those of ordinary carbon, illuminating gas, candles, and lamps, the color will be yellowish. It is to this cause we must attribute the bluish tinge which seems inseparable from the electric light. The eye, accustomed to the yellow tints of all other flames, instinctively compares the two, and that which is really white seems to us bluish, compared with the yellow one. Owing to its bluish whiteness, or its great intensity, or its disagreeable flickerings, we can no more look steadily at the electric lamp than at the sun itself. In consequence of this it has been compared with the sun, and as the inferiority is evident, some have been too ready to deny the wonderful qualities of the electric light. But what fire kindled by the hands of man could ever equal the serene and beneficent light of the sun!

From what has been said it will be seen that we can color the electric flame, and make it at will white or yellow, according as we allow the carbon to burn pure or place marine salt in the hollow of the lower pole. The tint can be further varied, if we

make use of the current to volatilize the metals. With copper, for example, the electric arc is blue; with zinc, it is violet with lithium (a rare metal which is applied to but few uses) it is red, and with mixtures of these metals, the tint produced is that of a mixture of the elementary colors. But, we must add, that this property of the electric light is of no use in an industrial sense, for the metallic matter is dissipated, and as soon as that happens, the flame becomes white, the color of intensely heated carbons.

Electric rays, it is true, are capable of traversing colored glass, like other rays; but the luminous intensity is greatly diminished, and it can no longer serve for illumination of any kind.

The study of the electric light, like that of the sun, possesses endless interest. When we make in a closed shutter a small opening through which a solar ray penetrates across a well cut glass prism into a dark room, the white color of the sun is decomposed and resolves itself into nine primary colors, from extreme red, which is first, to lavender, which is last, passing through red, orange, yellow, green, blue, indigo, and violet. If we take sufficient precautions —if the hole in the shutter is a sufficiently narrow slit to admit only a thin layer of rays, we discover in the midst of the rectilineal rainbow, which is called the solar spectrum, a series of very fine black transverse lines, having a well defined relative position, and arising from the absorbing power of a particular atmosphere around the solar orb. This is because in this atmosphere, owing to the intense heat,

are found a great quantity of metallic vapors, and the light rays in traversing them are partly arrested, causing the dark lines.*

The electric light offers the same study. Carbon in the solid state, like every other incandescent solid, gives a continuous spectrum formed of nine elementary colors, but not presenting any black lines. When the voltaic arc contains any metallic vapors, the elementary colors of the spectrum, due to the incandescent carbon, become gradually effaced, and in their place are shown particular rays very brilliant, colored according to the nature of the metal, and situated at places perfectly fixed in relation to the colors of the carbon spectrum. Thus marine salt gives two fine yellow lines, very close together; copper gives three or four blue rays, and lithium gives a single red ray. Aided by a little experimental artifice, we know how to make these brilliant rays become black, but we cannot in any way change their respective positions. By the appearance alone of these rays, brilliant, or black, and by the study of the place which they occupy in the carbon spectrum, we can tell the metal which is being volatilized in the voltaic arc, so fixed and certain are the relative positions of the lines to the metallic vapors.

---

* By means of a very remarkable, but unpretending instrument, called a *spectroscope*, modern science is able, by simply examining the light which comes from an incandescent body, whether terrestrial or celestial, to determine several things concerning its physical condition, and many of the elements which compose its substance.—A.

PHOTO-ELECTRIC MICROSCOPE.

For all the experiments of which we have been speaking, and for many others, we employ the photo-electric microscope. We cannot command the sun when we wish, but we can have an electric lamp always at hand. It is sufficient to prepare a battery to connect the current with the regulator, and the carbons with wires of greater or less length.

A microscope is used to magnify small objects.* But the light which illuminates the small object, on being spread over the large surface of the magnified image, is proportionally diminished in intensity, rendering the image so faint that only the bolder markings are visible. To remove this defect every microscope is furnished with reflectors or lenses, to concentrate upon the object a sufficient quantity of light to render its finest markings visible.

In the photo-electric machine the lamp is placed in a sort of lantern, which does not allow any light to escape to disturb the darkness of the room, and the greater part of the light thrown off by the arc is sent back by reflectors upon a glass lens. The latter concentrates the rays which it receives

* It is formed of a single lens, or of a combination of lenses, according to the class of examinations or exhibitions for which it is intended. Many of the finer microscopes display a skill in combining and arranging the parts, and an accuracy of workmanship which appear almost miraculous. They will magnify an object one tenth of an inch in diameter so that it will appear from sixteen to twenty-five feet in diameter, with very little indistinctness of outline and with no perceptible distortion.—A.

upon the object to be examined, so as to illuminate it intensely. Behind this object is placed the series of lenses which form the microscope. The image, vastly magnified, thus appears upon a large screen placed upright at the other end of the room, as we do with a magic lantern. In the table microscope the observer must place his eye upon the glass; but here, in the case of the projecting instrument, every one can, from his place in the room, see distinctly the object on the screen. By this means chemists have watched the carbons of the lamp, and studied the colorings of the electric light.

This microscope is very often used in public halls. The lecturer describes the things which the audience see depicted on the screen. All scientific experiments are susceptible of being thus projected. The most subtle observations on heat, and the most delicate experiments in electricity were thus rendered easily visible to immense audiences in London, by Professor Tyndall.

ILLUMINATING NIGHT WORKS.

Among other purposes to which it is devoted, the electric light serves to illuminate works carried on at night, the completion of which is necessary with the least possible delay.

During the construction of the bridge at Notre Dame, at Paris, for instance, a service of this kind was organized for the first time. Certainly it could

not be said that the work was conducted economically. The light was produced from a strong battery, and the price of the light was about four times that of oil; but there was a wish to study this novelty, and also to have the work carried on during the night. The bridge was thus very rapidly constructed.

This new method of lighting was applied afterwards at the works of the Napoleon Docks, also at those of the new Louvre, and some time later there was an attempt to use it at Strasbourg, in connection with the famous bridge of Kehl, across the river Rhine. In these works not only was a splendid illumination desired, but one sufficient to allow the laborers to see their work distinctly. As it was, the workman could see around him sufficiently to guide his own motions, but all minute details were invisible to him. The experiments were consequently far from successful. Hitherto there have not been found in the employment of the electric light sufficient advantages to compensate for the numerous inconveniences which its use involves.

After the first attempts, the magneto-electric machine was invented, and the light was produced of a better quality and more uniform. Experiments were then resumed. In later times it was proposed to light mines, substituting the electric lamp for the lanterns which each workman carried, and which threw but a dismal light upon the nearest objects. Experiments were made by M. Bazin, director of the slate quarries of Angers, and constructed with so much intelligence that, after a report was given

by the engineer who conducted the trials, congratulations and encouragements were addressed to him. It was determined to light an underground gallery, almost square, and about 140 feet long, the height being somewhat less. Two lamps were placed at suitable points, fed by electric machines of the Alliance Company. The results were satisfactory; the work became very easy, the oversight was certain, and the mining was carried on regularly. Every one was pleased with the change. After a time, however, in consequence of what circumstances has not been explained, the oil lamps were given back to the workmen, and every one regretted the termination of this brief underground experience of the electric light.

These experiments have made it plain that a magneto-electric machine cannot serve more than a single lamp. If the same current is sent successively into several lamps there is not the same intensity, and the current is considerably weakened. Each machine requires to be served by a special generator of electricity. Furthermore, it is to be noted that in augmenting the battery, or the swiftness of the rotation of the machine, we do not increase the intensity of the light. The arc may lengthen itself and become even very long, but it preserves always the same intensity.

It ought to be remarked, however, that these experiments made with the machine have succeeded, and that no further experiment has taken place since the time referred to; no factory or night work has been illuminated by the electric light. It would

be very easy, as we have already remarked, for factories and workshops to establish a system of lighting by electricity, and this idea, we are persuaded, must be adopted sooner or later.

PUBLIC ILLUMINATION.

One evening in December, 1844, during a thick fog, the people who were passing the Place de la Concorde, in Paris, were astonished by suddenly finding that they could see clearly, although the gas lamps at the distance of a few yards were invisible. A very intense light traversed the atmosphere, and lighted up even the remotest corners of that vast square. This was an electric light displayed from a machine situated about the middle of the square, and at a certain height above the ground. A powerful battery supplied the electricity, and during all the night it burned almost without variation. This experiment was conducted by M. Deleuil, an accomplished maker of scientific instruments.

Since that time numerous experiments of many kinds have been made. From the top of the Pont Neuf, for instance, the electric light has been thrown down upon the waters of the Seine. Again, a sort of lighthouse was established upon the top of the triumphal arch of l'Etoile, which lighted up the numerous avenues converging upon it; and similar experiments have been made at the Palais Royal and the Porte St. Martin. Every time a new regulator

was invented, the inventor demanded and obtained authority to give it a public trial.

All these experiments were more or less successful. Not the manner of spreading the rays, not the intensity of the light, not even the machine was at fault; but successively it was discovered that the disadvantage in its use was that the blaze of light would not radiate far from a given point. Around this point the brilliancy was intense, but at some distance from it darkness clouded the light. To increase the number of lights was merely to increase the expense, and no one would dream of doing so. Furthermore, it was found that the color of this electric light was dismal. Under its blaze objects became livid and ghostly, an effect due to the bluish tint of the rays. No one would desire that this pale gleam should replace the rows of gas lamps that make our streets gay up to the middle of the night. Nor is this all. Another inconvenience of the electric light remains to be mentioned. It makes objects appear in other than their true forms, both the lights and the shadows, instead of blending into each other, being strongly exaggerated. Everything is brought out in black and white; and if the lights are bright, the shadows also are intense. This results from the circumstance that the light, being a single point, gives no softening middle tint to the objects it illumines.

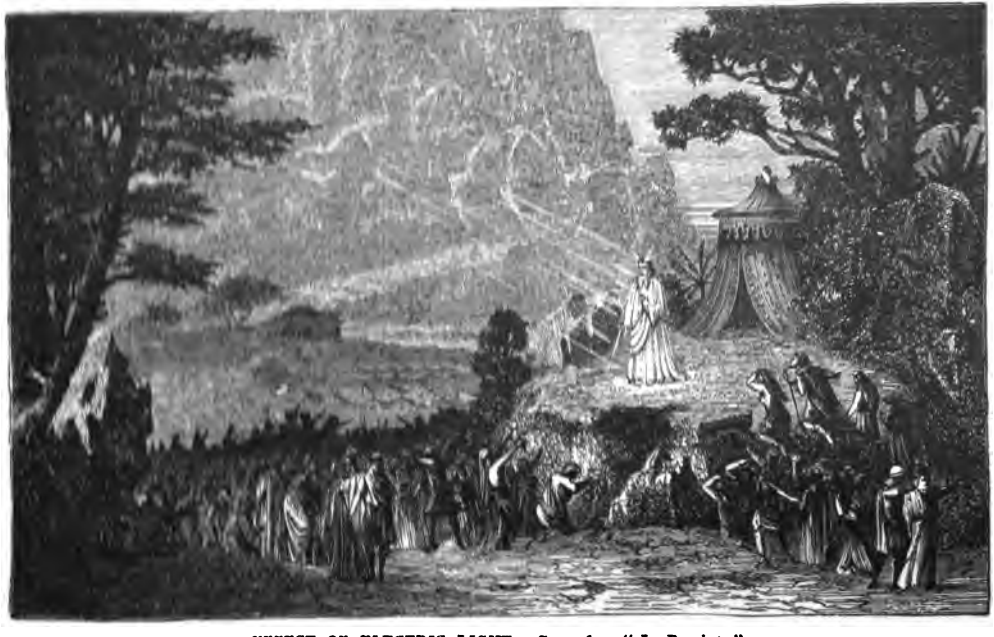
But if public lighting by electricity does not appear to be practical, it can be successfully employed on an extensive plain in particular circumstances. During the public fêtes of the 15th of August, for

example, the Place de la Concorde, and the Champs Elysées were, on one occasion, illuminated simultaneously by electricity. The obelisk of Luxor, in the centre of the former, was beautifully decorated with flowers and lights. Electric lamps threw their quivering rays afar, and the square was otherwise ornamented.

Some years ago it was desired to give a magnificent soirée at Versailles, in honor of the king of Spain. The splendid rooms overflowed with gold and luxuries ; the parks were ornamented with garlands suspended among the trees, and over all the electric light, in full splendor, illuminating the broad avenues, and green and velvety lawns. Each tree seemed on fire, and each saloon shone with lustres and crystals. The great fountains played, and added their monotonous murmurs to the music of unseen performers. It was exquisite and fairy-like, nothing being wanting. Since the famous fêtes of 1668, the Château of Versailles had never looked so splendid. That night was a triumph for the electric light.

LIGHTING OF SHIPS.

When daylight ceases a great lantern is hung out at the bows of ships, that their course may be seen and that other ships may give them ample sea-way. In quiet nights this bright light is seen from a considerable distance. But when the weather is foggy it is obscured, and becomes invisible at a very short



EFFECT OF ELECTRIC LIGHT. *Scene from "Le Prophete."*

distance. The inconvenience arising from this has caused learned men to inquire whether it would not be possible to make use of the electric light for ships. Its intensity would be so great that the ship would be seen at a great distance, and thus many misfortunes would be avoided. Collisions, for instance, in which one of the two vessels is almost always destroyed, would become very rare.

The cost of the electric light would be small; the magneto-electric machine, permanently installed, would be moved by the steam-engine of the ship, and the regulator, such as constructed by Foucault, would not suffer from the rolling of the vessel. It would be no great matter if one of the carbons broke, and the ship was left a few minutes in darkness. This new application of the light seems to offer decided advantages. It would be necessary, however, to use it with caution. Certain disadvantages might be rendered apparent in practice, and theory, which might explain them ultimately, is powerless to foresee them.

THE ELECTRIC LIGHT IN THE THEATRE.

In 1846, when representations of the opera of the Prophet were being given at Paris, it was resolved that the scenery should be unusually splendid—worthy alike of the music and of the poem. Two tableaux, in particular, were objects of special care and anxiety to the manager, namely, the rising

of the sun, in the second act, and the conflagration, at the end. The electric light was still a novelty, and its appearance in the first theatre in the world had something strange and solemn in it. It bore its part in accomplishing the immense success of the Prophet. At present there is hardly a ballet or an opera in which the electric light is not employed.

One of the operas in which its aid has been found most effective is Rossini's "Moses," produced in Paris some years ago. Although the scene is constantly illuminated, Moses never moves save in a special ray of light. One scene in particular is very remarkable. The people are in the middle of the plain; they are sighing regretfully for the flesh-pots of Egypt, and they wish to return. At this instant Moses comes forth, his eyes darting light, his whole body throwing out radiance, and his long white robe gleaming like the sun. Even before he has breathed forth his indignation his aspect causes the people to tremble. This scenic effect always gains immense applause.

In the interior of the wings or side scenes, are placed three electric lamps. From the top of the scenes on each side, an electric lamp is directed upon the entrance to Moses's tent, while a third is arranged in front, and strikes upon the actor's face. The rays of the lamp are concentrated upon the door. As soon as the tent opens, and the actor appears upon the scene, the electric current is launched upon him. The rays illuminate all this part of the scene, and the actor, previously instructed in what

path he is to move, walks continually in the midst of the light.

These are merely some of the ordinary effects. If a chief actor is to be placed in relief for any cause, that is to say, if he must shine out in the midst of a group placed in shadow, a jet of electric light is directed upon the spot where the actor will place himself. The lamp being directed, the rays move wherever they are wished, and when the moment comes, there is nothing to be done but to throw the current into the lamp.

At the Opera, the light is produced by the aid of batteries of forty or fifty elements or cells. A space under the roof is specially set apart for these batteries. Each evening an official mounts up to them, arranges them, examines them minutely, and when the performance is over, takes the cells apart. The electricity they produce passes into different wires, led everywhere throughout the stage. A little niche is made in the wall, where are to be found the ends of the conducting wires. The chief of the department attaches movable wires to these fixed ones, and thus can carry the current up to where the lamp is placed, wherever that may be. In this way everything is provided for, and there is nothing to be done but to act when the exact moment comes. The current of each battery is thrown into the wire destined to receive it. Afterwards, when it is desired to change the place of the light on the scene, the official goes to another spot to receive the current from another battery. Such is the organization of the service at the Opera. Sometimes

colored lights are used, either to make conspicuous a special actor, or a particular part of the scene. In "Faust," for example, Mephistopheles is from time to time illuminated by red light. In another piece of less success, an alchymist, reading destiny in a magic vase, is illuminated by a green ray which seemed to come from the vase itself. These lights are tinted by passing through colored glass.

In the final scene of the opera of "Moses," there is a very curious and difficult effect produced by the light. The people of Israel have crossed the Red Sea, and in the front of the scene, in partial darkness, the Egyptians are seen perishing in the waters. At the back of the stage, standing on a high rock, Moses holds the tables of the law. The Hebrews, grouped around him, sing the celebrated prayer, (considered one of Rossini's masterpieces;) the day is breaking, the electric lamps illuminate the scene, and at this moment, as the symbol of a new covenant, a rainbow appears.

To produce this illusion, two difficulties had to be overcome. It was necessary first to design a rainbow for the electric light; afterwards this bow had to be sufficiently intense to be seen from the auditorium without being extinguished by the other lights. An electric lamp placed about the middle of the scene, but concealed behind a rock, was supplied by a very strong current. Two batteries were used, in order that the intensity of the light should be great. On the other hand, the intensity of the light from behind was diminished without being noticed, because the front of the scene was obscure.

LAST SCENE — OPERA "LE PROPHETE."

Finally, by means of a special apparatus, the white light was decomposed into a spectrum, which painted itself as a rainbow upon the scene at the back, and all the rest of the light was lost or concentrated upon the side farthest from the bow.

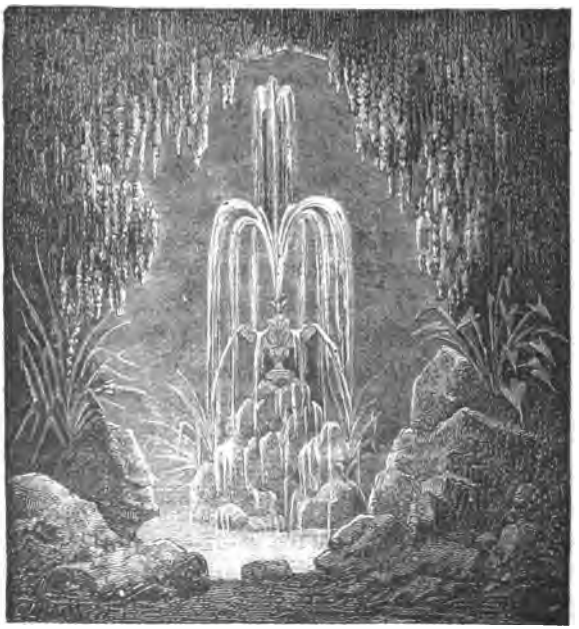
Other theatres have imitated these innovations of the Opera; often well, sometimes ill. It should always be borne in mind that to justify and deserve the name of progress, the electric light should be always used with intelligence.

LUMINOUS FOUNTAINS.

The electric light also serves to illuminate the water that rushes forth from fountains, and to cause it to appear really luminous. A vase of water is placed near an electric lamp, and all the rays are concentrated in the liquid; a rainbow, formed by a plate of glass, is pierced opposite the opening from which the water rushes. Some moments before the water is turned on, the lamp is put in action, the water illuminated, and the light penetrates into the liquid, impregnating the different parts of it, even to the smallest drops. When, therefore, the water rushes up, it continues affected by the electric rays, and carries with it the light, which, so to speak, it has drunk. Such is the luminous fountain. It shines very brightly when the hall or theatre in which it works is in a state of semi-obscurity.

Scientific explanation of this phenomenon is suf-

ficiently difficult. The light with which every drop is impregnated, is due to a series of interior reflections, which send out a diffused light. A sufficiently exact account of the difficult circumstances



Luminous Fountain.

that accompany this phenomenon has, however, not yet been given; all that has hitherto been seen in this strange fact, being that it is but a new means of amusing the public.*

* A sufficiently full explanation of this beautiful experiment may be given in a few sentences. The light, entering the vessel

Jets can be made differently colored; some red or blue, others green or white, and even while the fountain is playing, the color of the light can be changed, as if all the green water being exhausted, the blue water was laid on. To produce these effects, it is only necessary to put a bit of colored glass before the lamp. M. Delaport is the patented inventor of these fountains.

PHOSPHORESCENT BODIES.

Certain bodies have the curious property of preserving for some time the light with which they have been impregnated, and of becoming themselves sources of light. This property is only apparently analogous to that possessed by the water of which we have spoken. These two phenomena must, however, be ascribed to different causes. Phosphorescent bodies have a color of their own; they do not give back the same light they have received. Thus certain bodies illuminated with a white light, remain blue; others become red, and whatever be the color of the incident light, phos-

exactly opposite where the jet leaves it, and moving in the same direction as the jet, must enter it and follow it in its entire course while unbroken, without being visible. Should the jet bend, the light, endeavoring to escape at the curve, will be reflected back, with hardly any loss, and thus made to follow the curve. When the streams break into drops, the reflection is at such an angle as will allow the light to escape from the drops in brilliant coruscations as they fall. With a ray of sunlight, in a very dark room, this is one of the most entrancing experiments which can be made.—A.

phorescent bodies have always their own proper color in the dark. These substances are very numerous, and their study has been made the object of a very elaborate work by M. Becquerel, who has striven to discover the properties of these phosphorescent bodies, and the time during which each of them preserves its luminous impression. He has succeeded in rendering the subject accessible to everybody. The electric light is an appropriate agent for producing phosphorescence in bodies. It is invariably made use of when phenomena are to be displayed on a large scale in an amphitheatre. By the aid of this agent, bodies which had been in comparative obscurity, are not only rendered self-luminous, but it serves to modify the flood of ordinary light which falls upon them. Phosphorescent bodies, on the other hand, have been often employed to augment luminous intensity. In the miner's lamp, invented by M. Ruhmkorff, for instance, phosphorescent particles were contained in the serpentine acted upon by the electric spark.

The phosphorescent phenomena has not yet been successfully employed in theatres. An attempt was made at Paris to represent scenically remorse for a crime committed, by making certain luminous writings shine out boldly upon the wall, as a reproof to the criminal. But the attempt failed, and was ultimately abandoned.

DRUMMOND LIGHT.

Often, when there is need of great luminous intensity, the drummond light is employed. Less

brilliant than the electric light, it is softer, more regular, and its yellow tint is more agreeable to the eyes. In the greater number of theatres it is employed in place of electric light. It is only at the Opera that the latter holds undisputed sway.

The Drummond light is formed by a flame of illuminating gas, into which is introduced a current of oxygen—the vital gas which maintains life and combustion. This causes the flame of the gas to burn with intense heat. This flame is directed upon a small piece of lime, which becomes highly incandescent. It is the light arising from the lime that produces the Drummond light. This fact once established, the lamp is easy to comprehend. Two tubes are brought together, one bringing gas from a gas-burner; the other, oxygen from a bag. These tubes, kept apart until they reach the flame, terminate in a concentric burner. The current of oxygen rushes out, surrounded by a flame of illuminating gas. Opposite is a morsel of lime, prepared and placed on a support which can be advanced and drawn back at will.

The light is concentrated and directed to the required spot by a mirror, or lens, and the required effect is produced. This lime lamp is more convenient to manage, and less expensive than the electric lamp.*

* In producing the Drummond light, the imperfections caused by the wasting of the lime and the necessity for frequent renewal, have been obviated by the use of zirconium. This substance is much more durable than lime, and gives a more brilliant and much more uniform light. The only objection is its high price.—A.

By a series of experiments it has been found that the quantity of light sent by the sun to the earth, is equal to 22,500 Carcel burners, burning each about one and a half ounces of pure rapeseed oil per hour. On the other hand, it has been found that the quantity of light given forth from an electric lamp of the greatest power possible, upon the same surface, at three feet distance, equals only one hundred and twenty-five burners, and the Drummond light only twenty burners.

At Paris, in the square of the Hotel de Ville, comparative experiments have been made between the ordinary illuminating gas, and an improved Drummond light. According to the inventor, this new light will be more advantageous than that of gas; it will be cheaper, and for the same quantity of light fewer jets will suffice. This light is obtained by burning illuminating gas in combination with oxygen. The flame is directed upon a piece of magnesia, instead of lime. Magnesia is less friable than lime, it stands a longer time, and gives to the light a very fine bluish tint, which renders it as white as the sun or the electric lamp. It has, moreover, this advantage, that the flame is stable not oscillating in the disagreeable manner of the electric light.

The actual practical value of this new mode of lighting must be judged of by the future.

BOOK FOURTH.

ELECTRO-PLATING.

CHAPTER I.

GOLD PLATING—HISTORY OF ELECTRO-PLATING.

ELECTRO-PLATING came into existence only yesterday, so to speak, though certain persons trace it back for thousands of years, and assure us that modern science has only the honor of rediscovering what was well known to the ancients. It is supposed that the Egyptians knew the art of depositing copper and other metals upon vases and urns, by means of the electric battery; because, in the tombs of Thebes and Memphis, are found certain objects covered with a thick layer of copper, which presents to the microscope the same appearance as galvanic deposits. In the sarcophagi, again, curious pieces of metal have been found, so light and thin that it would have been impossible to obtain them simply by melting or hammering. This led people to suppose that moulds of wax were anciently covered

with a galvanic deposit, and that afterwards the wax was melted, leaving the thin layer of metal by itself. Moreover, it has been pretended that old alchemists, those who searched for the philosopher's stone, knew how to cover objects with a coating of gold, and that pretending they had discovered the great secret, they sold images so covered for articles of solid gold.

In spite, however, of these surmises, it remains incontrovertible that it is only since Volta's invention that we have obtained metallic deposits. This savant found out, almost immediately after his discovery of the battery, that by passing the electric current into a saline solution, a deposit of metal was formed at one of the poles. Since then this question has occupied much attention.

In 1838 Jacobi announced to the Academy of St. Petersburg, that he had succeeded in obtaining copper plates, giving an exact impression of designs engraved upon the original. At the same time, Mr. Spencer, in England, made the same discovery. The copper deposits were found to be suitable for copying medals, bas-reliefs, and for printing characters. A letter, publicly distributed, was printed by this process, and a large number of copies struck off. Jacobi continued his studies, and in 1839, in a letter to Faraday, he describes the copper-plating process, and proclaims its industrial importance. We may therefore consider him as the chief inventor of copper plating, that is, the art of depositing copper upon certain bases, by means of electricity. M. de la Rive, who followed up the discovery, succeeded

equally well in depositing gold and silver. His work was published in 1840. Inventors worked much and quickly in these times. Three years, from 1838 to 1840, ushered in the greatest discoveries of modern times—the electric telegraph, electro-plating and daguerreotyping.

M. de la Rive's process was not practical. But Elkington, who afterwards worked long in the same field, found a practical method of depositing gold, which is employed to the present day. He took out patents and transferred them to M. Christofle in France, whose establishment has become famous.

What Elkington did for gold, Ruolz did for silver. He also took out patents. Other inventors succeeded, and among them many men of science. After a time Elkington, the inventor of gold plating, and Ruolz, the inventor of silver plating, handed over their patents to M. Christofle, who immediately organized his vast factories; and since that time the patents have for the most part fallen into the hands of the public and become common property.

PREPARATION OF THE ARTICLES.

Electro-chemical gold plating is the art of covering objects of different forms with a layer of gold, by means of an electric current. This covering of gold is laid on by a series of operations which may be grouped in three or four essential processes. The first is the preparation of articles, which is the most

important, for all the success of the subsequent operations depend upon it. There are different methods of preparing the articles.

Objects coming from the hands of the manufacturer or carver are always, by handling, covered with a thin layer of grease, which prevents the adherence of the gold. The first step accordingly is to clean the articles and render their surfaces entirely homogeneous, and put them into a suitable physical state for the reception of their metallic covering.

When the object to be operated upon is in bronze, it is placed on the fire and made red hot. When it is in brass, however, it cannot be treated thus, as such severe treatment would injure the material; so it is washed instead, in a concentrated solution of soda. The heating to a red heat, or the washing in the alkaline bath, removes the grease, but it always leaves a thin coating of oxide. To remove this, the articles have next to be scoured with very fine sand. They are then placed in an acid bath, hot for the small articles, cold for the large ones; and they are suspended there by copper hooks, with wooden handles, that the hand may not touch them. They are left in the bath until they become reddish in color, and are afterwards taken out, washed and brushed. Their preparation is finished by putting them into two strong acid baths, the second of which, called the bleaching bath, keenly corrodes the metal. They are then well washed in water, dried in dry sawdust, and carried off to be electro-plated.

When the articles are in iron or zinc, the operator commences removing the grease from the arti-

cles by subjecting them to a bath of soda. They are then washed in water, cleaned with pumice stone and brushed with a very stiff brush of boars' bristles, mounted on a lathe. If the articles are too delicate, or too large to be put under the lathe, they are brushed by hand with suitable brushes; they are then dried in saw-dust and carried to the gilder. For silver the processes are the same as for iron and zinc; but before being subjected to the operation of the pumice stone, the articles are first bleached, then made red hot, and then plunged suddenly into a slightly acidulated bath. Most of these diverse operations, especially, that of the pumice stone, are performed by women. The various articles are given into their hands for being operated upon, and from time to time workmen pass through the workshop and carry off to the gilder the various articles as they are prepared. Extreme care must be taken not to touch them with the hands after they have gone through the grease-removing process. Their surface being at that time very clean, is excessively sensible to the touch. All the pores of the metal, so to speak, are open, ready to receive or *inhale* the deposit that is to be placed upon them.

BATHS OF GOLD.

The composition of the gold bath is well known. In detailed treatises we find specified the proportions of the substance with which the best deposits are obtained. Manufacturers are to be met with

who will not divulge the secrets of their baths, nor tell whether they mix inferior matter with useful liquids; whether they possess a secret method of operation, or whether they have found some process which easily gives them beautiful effects. But the general nature of the bath is the same in all factories.

The operator dissolves one and three fourths of an ounce of gold in aqua regia, and evaporates it. When the liquor is as thick as syrup, the tepid water is put in and one and three fourths of an ounce of cyanide of potassium is gradually added. This last chemical body, on account of its important properties, is one of the most valuable in chemistry. This operation yields upwards of fifty quarts of the solution of gold and cyanide. The liquid thus obtained is boiled for several hours, and the articles to be plated are then put into the boiler. This boiler is itself heated during the operation to about seventy degrees. The gilder might operate with a cold bath, but the deposit would not be so thick nor the colors so rich.

Before putting the articles into this bath, they are rinsed in alcohol, afterwards in an acid bath, and lastly washed in water. Only after this last preparation has been gone through with by the side of the boiler, do we put the articles into it. They are left there a certain time, according to the thickness of plating desired. A layer of gold can be deposited in a few minutes. In order to decide how much gold has been deposited on the articles, they are weighed before they put into the bath, and again after they are taken out.

All the metals are plated equally well in this bath. Upon certain substances, however, such as steel and aluminum, the deposit of gold will not adhere. They have first to be covered with a thin layer of copper, and to this the gold adheres. The copper adheres to the metal and the gold to the copper, so that the process is a solid one.

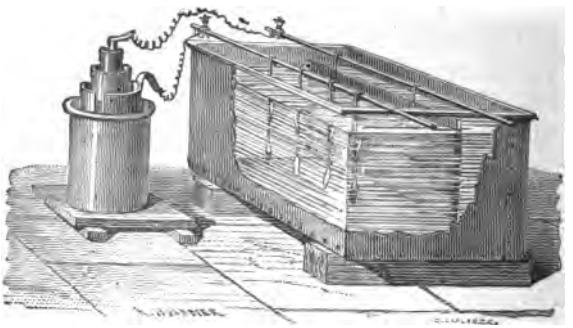
MACHINERY EMPLOYED.

The machinery employed to make the deposits is very simple. The current of a Bunsen battery is brought by wires to the gold bath and connected with two metal rods placed above it. The articles to be plated are attached to these rods by metallic hooks, and are entirely covered by the bath. But it must be observed that they are suspended to the negative rod, which communicates with the zinc pole of the battery. To the other rod is suspended a plate of gold or silver, according as the bath is to be used for gilding or silvering.

The electric current from the battery passes into the rods, and thence, by the metallic hooks and articles, it descends into the liquid through which it passes. The circuit of the electricity is thus complete, and the current passes from pole to pole. The passage of the current through the liquid causes very curious and interesting reactions. Thus, as Volta recognized, electricity decomposes metallic salts, and deposits the metal at the negative pole. This is what happens here. The salt of gold tra-

versed by the current, becomes decomposed, and the gold is deposited at the negative pole, where the objects are, and these become plated. Great care however must be taken in establishing the metallic communications, that the articles are equally traversed by the electricity, or else they will be unequally plated.

As the gold is deposited the liquor becomes poorer and poorer, and contains less of the precious metal. Consequently, if care be not taken, the deposit will cease in time, and then, if the current stops, the gold will be redissolved from the objects by the action of the impoverished liquid. In order to avoid this pos-



Battery for Silver-plating.

sible disaster, there is placed at the positive pole a plate of gold; so that, in proportion as the bath becomes weakened at the one side, it is enriched at the other. At the positive pole a quantity of gold s dissolved from the plate, precisely equal to that deposited at the other pole. There is thus kept up a continuous process of supply and demand.

BATTERY FOR SILVER PLATING.

The apparatus is therefore composed, first of a battery, metallically connected with the rods of the bath, and, secondly, of a vase or box, formed of wood, stoneware, or some other non-metallic material, containing the bath, in which on one side are plunged the articles to be gilded, and on the other side the plate of metal that is to supply the waste. The battery throws off unhealthy vapors, and it is well to place them outside of the shops where the workmen operate. At Christofle's, the battery is placed outside, in a great shed, surmounted by a very tall ventilating chimney.

FINISHING OPERATIONS.

On leaving the bath, the articles generally present a tarnished appearance, which much reduces their value. Consequently, they have to undergo several operations for the purpose of polishing them and giving them that color and brilliancy so much esteemed in commerce.

The first of these operations is accomplished thus: A workman rubs the article energetically with a brass brush, consisting of long wires gathered into a bundle at one end. He who is operating takes the brush by the handle and rubs the article, polishing particularly the parts which are to represent the design. The article to be brushed is put into a thickish protecting liquid of some kind which forms a thin mucilage, and the brush, by means

of it, rubs more softly. But for this protecting liquid there might be danger of scratching the deposit.

When the articles are flat, without any design in relief, they are polished by machinery. They are submitted to a brush working on a mandrel, which turns very rapidly, the axle making six hundred revolutions per minute. The workman directs the operation, holding the article under the brush. A stream of mucilaginous water falls constantly on the brush, and rolls away below. One workman can, in this way, do as much polishing in a day as ten men working by hand.

This preliminary brushing completed, the articles are next subjected to the coloring process. The colors are brought out upon certain special points, and the contrast of these points with the points which have simply been brushed, form divers tints, from which happy effects are deduced. A liquid, which has been improperly called molten gold, is prepared, containing alum, nitre, red ochre, sulphate of zinc, iron, and common salt. This mixture is spread over the gilded surface of the article with a camel's hair pencil. The articles are then held over a clear charcoal fire, which causes the mixture to dry up and assume a brownish tint. They are next plunged quickly into a solution of chlorohydric acid. This removes the mixture with which they were coated, but, by the deposit which it leaves upon the parts which were covered with it, effects a physical transformation, which modifies their color. Lastly, the articles are dried in the ordinary way, in sawdust.

After being brushed with the brass wire, the articles have a hard and crude polish. They have not that velvety smoothness which equalizes the polish over all the surface and softens the colors. A third operation of burnishing is accordingly gone through, in order to give the articles the requisite finish. The burnishers are composed of very hard stone, or of steel, beautifully polished, and set in wooden handles. The workman rubs up the articles with one of these until the surface shines and is perfectly polished.

These different operations vastly increase the cost of the objects gilded by electricity. The layer of gold deposited upon the articles is in itself exceedingly thin, and it is not that which makes the prices great. Silver tea-spoons are perfectly well plated with no more than six cents' worth each of the precious metal. The public have to pay, not for the gold, but for the numerous processes that precede and follow the deposit. It should be remembered, however, that objects thus plated cost only about half as much as those which were obtained by the old process.

SILVER ELECTRO-PLATING.

Silver plating is at least as important as gold plating. As the layer of gold is very difficult to obtain, and as the beauty of the deposit depends in great part on the preparation of the surface, it sometimes happens that articles are at first silver

plated before they are gold plated. Silver plating is much more easy, and a silver surface is well adapted for the gold bath, and enables the gilding to be more successfully accomplished.

Silver plating should not be separated from gold plating. They are two similar operations, which give analogous effects, and are often completed by each other's assistance.

Objects that are to be silvered are submitted to the same preliminary operations and the same cleansing as those to be gilded. The composition of the bath is the same, as is also the preparation; and the basin itself, as in the former case, is inclosed in wood, lined with gutta percha, to prevent the absorption of the liquid. The cyanide of silver, which is to be mixed with the cyanide of potassium, ought to be exceedingly pure, and prepared at the factory itself, as that which we find in commerce will not do for this purpose.

When the argentiferous bath is prepared, a positive pole of plates of pure silver is arranged, and at the negative pole are placed the articles to be silvered. The different phases of the operation are the same as for gilding, but the deposits are made more rapidly. Thus, four ordinary electric elements can deposit in four hours about one pound of silver; or, to put it another way, silver plate nearly five thousand tea-spoons, provided no time be lost. Upon leaving the bath the objects are brushed with brass wire brushes, and burnished as in the case of the gold plating.

Generally the deposit of silver is dull and heavy.

It happens sometimes, however, by chance, and by a series of circumstances unknown to us, that the deposit is brilliant. Careful study has been directed to the solution of this mystery, with the view of having at will a dull or a polished surface. It has been found that by putting sulphide of carbon into the bath this object can be gained. About four drachms of this liquid is sufficient for upwards of ten quarts of argentiferous liquid. The mixed liquid, after being left to stand for a time, is poured off into the bath, and a kind of black powder is found at the bottom of the vessel. There is formed a small quantity of sulphide of silver, and it is probably owing to this material that the deposit on the articles to be plated is so brilliant. No brass wire brushing is required for articles so silvered.

In spite of the utmost care it sometimes happens that articles are ill plated, and in such cases, if it is desired not to lose the precious metal, they are *un*-plated. Should the article which has been ill silvered be of copper, it is plunged into a bath consisting of a mixture of nitric and sulphuric acids and water, heated to 70°. In this the silver is dissolved gently; the copper is not sensibly attacked at the beginning, and by the weight of the object we can estimate the amount of the silver removed. For the dissolving of gold common salt is put into the composition, which is applied cold. If the basis of the article is iron or steel it is stripped of the coating of precious metal by the electric current, the article operated upon being suspended at the positive pole.

Silvering is a more frequent operation than gild-

ing. To it belong the principal works of art that have been achieved, their number being very large. A multitude of feats of skill in manipulation, and of little expeditive processes, are put in practice, not only to facilitate and regulate the deposit of silver, but also to obtain various effects. Every factory and every manufacturer has secrets which he conceals from the eyes of all strangers. All the employees are not in the secret of the manufacturer. Only the workmen who deserve the greatest confidence—the number of whom is as limited as possible—are trusted; even they do not possess the whole secret, but each one has only a special part of it. Thus it is that, although the means of silvering are well known, many of the empirical processes, and the feats of manipulative skill, by means of which special effects are obtained, remain still unknown to the public.

Besides the operations which are more or less concealed, and which consist, it is necessary to say, only in the smallest details, such as boiling a bath before or after a certain operation, plunging the article to the bottom or merely dipping it at the surface, there are several processes common to all, and which are in no sense secret.

It has been remarked that those parts of the object that are hung nearest to the positive pole are covered with the thickest layer of the precious metal. Care is consequently taken to place in this position the points that are to be most exposed to friction in polishing, and which on that account require a greater thickness of plating. The silver

soon falls to the bottom, and above there remains almost only the pure water. As the solution of silver is concentrated at the bottom of the bath, the objects would, on that account, be very unequally silvered, were it not that the workmen stir the bath frequently. When the silver becomes exhausted, it is necessary to keep up the supply of it by plates. But the cyanide of potassium also becomes exhausted, and at the end of some time there is no longer in the bath sufficient alkali to dissolve the silver, and the liquid no longer works. This potassium is renewed by adding from time to time some cyanide of *calcium*, which, after passing through different chemical changes, finally reforms the alkaline solvent. This happy idea is due to a workman in Christofle's establishment.

It is useful to know these processes, in order to judge of the minute precautions that require to be taken in order to produce good results.

RESERVES.

In beautiful articles of goldsmiths' work are sometimes combined several metals. Gold and silver commingle, and by their union form harmonious contrasts. Thus, for example, a garland of flowers: the stems and the leaves are plated in green gold, each with tints more or less deep; the flowers are formed by silver, and the stamens, those delicate depositories of the honey, are plated in ordinary

gold. All these tints imitate the natural colors, and simple designs of iron and copper become magnificent objects of art, painted and carved by the soft and silent influence of electricity.

Green gold is obtained first of all by mixing a bath of gold with proportions, more or less varied, of a silver bath. The deposit is a variable combination of gold and silver, which has a greenish tinge. Red gold, again, is produced by a mixture of gold and copper baths, while yellow gold is manufactured in the ordinary gold baths.

When we wish to obtain a deposit upon the whole surface of an object, we put it entirely into the bath; but if we wish to have deposits only upon certain points, we must protect all the other parts, and prevent them from taking on the layer of plating. This process is called "reserving," or shielding. With a hair pencil we paint upon the surface we wish to reserve a varnish made of copal, oil, and chromate of lead. This varnish does not allow the electricity to pass. The object painted over with this varnish on the spots which are to be reserved is put into the bath and worked in the ordinary manner. The varnish resists the liquid in which the object is placed, and prevents the plating from adhering to those parts.

USES OF GALVANIC GOLD PLATING.

When we know how to gild or silver plate metals, it might be inquired if we could not operate in the

same way upon all sorts of objects. Savants have considered only the most important results; it is to others, especially to workmen, that the credit belongs of finding out all the practical uses of these first discoveries.

Who would think, for instance, of depositing gold and silver upon silk? of embroidering cloths, of covering laces, with metallic layers, so fine and so light that the needle of the cleverest seamstress could not imitate them? Who could have thought of gold plating ball-room robes? When the problem was first proposed it appeared to be almost impossible of execution, and all manner of difficult questions were raised. Would it not be necessary to plunge the cloths into corrosive liquids—to design the embroideries by hand—to force the electricity to deposit gold upon the points indicated? Certainly; but all these difficulties have been overcome. We sometimes admire in balls the delicate toilettes, surcharged with magnificent embroideries. We are astonished that a hand sufficiently skillful could be found to weave together so much gold and so much silk, and yet everything be so fine and light. The threads are covered with so thin a layer of gold that the weight of the garment is not sensibly increased; and, in gilding the richest ball-room robe, the operator consumes only a few cents' worth of metal. Nay, more, organic matters have also been covered with gold and silver. At Berlin, for instance, they plate fruits, flowers, fruit baskets, etc., with gold, making little ornaments, which are very delicate and highly prized. The fruit is pierced and lifted

with a pin, and its surface covered softly with plumbago (black lead finely powdered.) It is next carried to the copper bath, where a layer of copper is formed over it. Over the copper is deposited gold by the usual process. The pin is then withdrawn, the interior fruit left to dry, and there remains nothing more than a metallic envelope, which has exactly the form of the fruit, with all the minutest details perfectly preserved.

In France they manufacture light and beautiful little baskets in silver. A very slender and very light osier is brought from Germany, which is plaited into neat letter baskets. These baskets are covered with a layer of plumbago, and receive successively a coating of copper and of silver, and they are finished. The osier dries in the inside, and there remains a basket apparently plaited of silver twigs.

In France and Belgium they even gild glass and porcelain, and the layer adheres. The operation is commenced by depositing on the surface a light veil of silver, which is done in an ordinary bath containing poppy oil. This oil gives a deposit—it is not known how—of adhering silver. Afterwards it is covered with a layer of copper and a layer of gold. They have commenced even to make, by this process, mirrors in which the mercury is replaced by a layer of silver.

Nothing limits the uses of electro-chemical gold and silver plating. The processes gone through are more or less easy, and more or less known and explained, but what does it matter to industry, if prudent science advances only in a groping manner,

where she can explore? Industry profits by all discoveries, and if she does not understand them, that understanding is not indispensable.

ANCIENT PROCESSES.

Previous to the discovery of electro-plating, objects were plated by three processes, which were at once difficult, uncertain and costly.

Gilding by immersion is still employed for washed jewelry and small objects. These are dipped in an auriferous bath. The preparation of this bath is very difficult, and it is almost impossible to exhaust the bath of all the gold in it, whereas with electricity every particle of gold in the bath can be used. Those operations which precede and follow the gilding, are the same as those which have already been described. The layer of gold is in this instance extremely thin, and can augment the deposit only by roundabout means. It happens moreover that the gilding is irregular and the dipping has to be repeated often.

As mercury gilding is no longer carried on, all we need say of it is that it consisted in dissolving gold in mercury, as we dissolve sugar in boiling water, until it formed a sticky paste, and then painting the articles to be gilded with this mixture by means of a brush. Having been painted, the articles were placed in an oven, the heat of which caused the mercury to evaporate, and the gold to adhere to the spots where it was pasted. This ordeal having been

gone through, the articles were finally burnished. A fatal peculiarity of this process was that all the men that worked at it soon died, killed by the fumes of the mercury.

The process of gilding by means of gold leaf is too well known to require mention here.

Most of the processes of gilding formerly followed have now been abandoned, owing to the discovery of electro-plating. The numerous inconveniences which they presented are now avoided, and the advantages of the new process are incalculable.

CHAPTER II.

GALVANIC COPPER-PLATING.

In electro-plating, we not only cover with a layer of metal, gold, silver, or copper, any specific object, however fashioned and carved, but we also seek to reproduce a model of the original article as often as we wish, and to obtain new copies of the identical form which may be submitted to the operation. Deposits of copper are produced under the same conditions and regulations as those of gold or silver. A coating of copper, as we have seen, is often had recourse to to facilitate the adherence of the precious metals. Copper plating in thick layers, upon a model, is managed by means of processes easy to understand after what we have said above, and very easy to execute. Consequently, when we wish to reproduce, with scrupulous exactness, a copy of any object whatever, we submit it to the operation of galvano-plating. This art applies to all others and comes to their aid, whether to reproduce indefinitely, and thus make common, statues and bas-reliefs, or to manufacture candelabra, fountains, or

public colums, or to preserve stereotype, engraved, or typographical plates—innumerable uses as frequent as they are cheap.

MACHINERY.

The apparatus made use of to copper plate objects, whatever they may be, is simple—electricity being produced in the bath as in the former cases. In the bath is placed a solution of blue vitriol, or sulphate of copper, like that which we use in the Daniell battery, and into this liquid we plunge the object. This preliminary process forms in reality a battery, and the bath becomes a generator of electricity. This fact has caused the apparatus employed in plating to be considerably simplified.

In the copper bath is placed a porous vase of unglazed porcelain, filled with dilute sulphuric acid, and with a plate of amalgamated zinc. This forms an actual Daniell battery, with this modification, that the external basin, containing the sulphate of copper, is very large and can contain at once several porous vases. Electricity is produced in these vases by the chemical reaction of the acid upon the metal; the negative pole is the zinc itself, while the positive pole is in the bath of sulphate of copper, as in the Daniell battery. To form the current, it is only necessary to connect the two poles by a metallic wire.

The mould or object to be copper plated is suspended in the bath, and becomes the positive pole,

if care be taken to metallize it—that is to render it able to conduct electricity. As soon as the circuit is closed, and the mould is connected with the zinc, the current passes and the copper commences to be deposited. Very soon, however, in proportion as the copper is deposited, the bath becomes exhausted, and, as in electro-gilding, it is absolutely necessary to keep the liquid from becoming exhausted. For this purpose a small cloth bag is filled with crystals of blue vitriol, which gradually dissolves in the bath and keeps it always at the same degree of saturation.

This apparatus is very simple. It contains at once a battery and a bath; it does not demand the employment of a special battery, and any one can set it up at his own house and commence copper-plating for himself.

MOULDS.

In gold and silver plating it is required to cover a certain object with a layer of metal, and for this purpose we plunge it into a bath. Here it can either be covered with metal or a model of it reproduced. In the first case the object itself is plunged into the bath, the surface being rendered metallic, if it is not so already, by a coating of plumbago; in the second case it is necessary to obtain a mould of the article and act upon the mould.

Moulds are formed out of any plastic substance, and all the details indented in the moulds, even the

most minute, are afterwards covered with copper. The plastic matter out of which the moulds are formed, varies; sometimes it is wax, sometimes gutta percha or plaster.

Thus, to reproduce a medal, it is moulded in plaster of paris. The surface of this mould is afterwards covered with a thin layer of stearine to preserve it from the corrosive action of the bath. This is left to dry, and, after having reserved the exterior parts of it, it is plunged into the liquid. If the medal is in relief, the mould in plaster will be hollow; and the deposit in copper will cover the hollow with a homogeneous layer, which will go on increasing more and more. When a sufficient thickness is attained, the medal is taken out and the mould is detached from its impression. If it is desired that the medal be produced only on one face, its removal will be easy and the mould will serve several times.

The reserving of the exterior parts is managed by not metallizing those parts where no deposit is required. This metallization is necessary for all the moulds, the aim being to render their surface conductors of electricity. Some substances are good conductors; others, on the contrary, such as resin, glass, porcelain and ordinary plastic materials, rebel against the action of electricity, and allow themselves to be electrified only at the points immediately touched. They are bad conductors. In an electro-plating bath, in order that the deposit may take place, the surfaces to be copper plated must be conductors, and the electricity must be able to circulate freely over them.

On this condition alone, will the deposit take place.

The metallization of moulds is done with plumbago, a powder which very readily conducts electricity, and which is obtained from graphitoid carbons. We find out first if the plumbago possesses the properties required; afterwards we pass a badger blender, dipped in powdered carbon, softly and frequently over all parts of the mould, until the layer is uniform throughout, and every point be covered. Finally, we make the surface brilliant by means of a fine brush. We then surround the edge of the mould with a copper wire so as to touch upon the outline of the plumbago; and by this wire we suspend the mould in the bath.

Surfaces of objects can also be rendered conducting by moist metallization. To accomplish this, nitrate of silver is dissolved in alcohol, and after steeping the articles in this solution, they are dried. There is deposited upon them a saline layer. They are then exposed to sulphurous fumes which cause the silver to be reduced, and the surface to become black and conducting. This is the method made use of by Elkington in England, and Piéduller in France, for metallizing vegetable substances. Thus we metallize flowers, fruit, silk threads, glass and crystals, and when this first chemical deposit is obtained, we submit the substances to electro-chemical baths.

Moulds in wax or stearine are formed and prepared in the same manner. But all these plastic materials are rigid and cannot be taken off easily. It is often necessary that the mould should not break when the object moulded is removed, otherwise the expense

would be considerably increased. The mould should be made to serve many times.

Very frequently gutta percha is used for moulds in galvanoplastic operations. And here it may be remarked that if this art has made great progress—if it has arrived at great perfection, it is owing to the employment of gutta percha. It is sufficiently elastic to reproduce objects faithfully; it is not altered by contact with alkaline and acid baths; and it can be used for any length of time. The process of moulding with gutta percha is very simple. A quantity of the substance is taken and softened in boiling water; then well kneaded with the fingers, and the object to be moulded is surrounded with it. This layer is carefully pressed all around, and takes an exact impression of the object. Thereafter the gutta percha is left to cool and it is then taken off. Having previously moistened the object with soap-water, and mixed the gutta percha with plumbago, the stripping of the moulds is easily done and the process finished.

The making of the moulds is the most delicate and most important part of galvanoplastic art. It is particularly necessary to render the metals clean and otherwise suitable to be taken to the baths. "As the surface is, so is the deposit," is a dictum ever borne in mind by the workmen.

MASSIVE GALVANO-PLATING.

The copper deposit removed from the mould is only solid when it represents massive objects, and

when it is very thick. Then alone the deposit holds itself together, and runs no chance of breaking by its own weight. Generally, the deposit is thin, and requires to be supported. In the case of a hollow mould, for example, the deposit will produce with astonishing rapidity and fidelity, the contour of the mould. The reproduction will be in relief, and when the mould is removed, the deposit will alone remain; but if the model is a tall piece of sculpture, or an ornamental pillar, etc., the cast will have no strength.

To remedy this inconvenience, Christofle filled up the hollows with pieces of brass, and afterwards heated the mass. Yellow brass melts at a much lower temperature than that required to melt copper. Thus, in the experiments of Christofle, the brass in the interior melts, fills the space and distributes itself uniformly all round; while the copper is neither melted nor deformed. It preserves exactly the form of the surface of the mould. The melted brass in the inside is left to cool and harden, and when this is done, the mould has the appearance and much of the strength of the solid sculpture.

GALVANOPLASTIC STATUARY.

When we wish to produce a high relief, every precaution must be taken. Round objects, statues, or bas-reliefs, in which certain parts in relief are concealed by others that come in front of them, are difficult to mould in one piece, as the mould cannot

be easily removed from the galvanic deposit. Thus, in a statue, it is necessary to produce at once both the front and back of the head. And to have a complete statue, the mould must be broken. Most frequently, such effects are produced by separate parts, many moulds being employed, one for each part, the different portions being afterwards united. In a statue, the first piece to be moulded is the face, then the back of the head, then each arm, when these are separate from the body; these various portions are afterwards joined together by an easy process, in such a way that the soldering is not visible.

There is, besides, a means sometimes employed by which round casts are made in a single piece. A complete mould is constructed either in many parts, or in one. This mould is hollow, and it is upon the internal surface that the metal is to be deposited. A body of platinum wires is introduced into this shell, presenting rudely the form of the object. These metallic wires are attached together, and follow the mould in its chief sinuosities, but without touching it. When thus far prepared, it is plunged into the bath. The liquid penetrates into the mould by the open base, and the deposit is made at the same time in all the interior parts. Electricity is communicated by means of the platinum wires which communicate with the positive pole of the battery, and causes the electricity to traverse and decompose the liquid. The mould, we must add, is covered with plumbago, and communicates with the negative pole. The deposit then gradually

forms upon each part. It is necessary to take care that the wires do not touch the mould in a single point, for no metal would be deposited upon that point, because the electricity would pass directly from one pole to the other without crossing the liquid. To ensure this, the wires are enclosed in insulating tubes of glass.

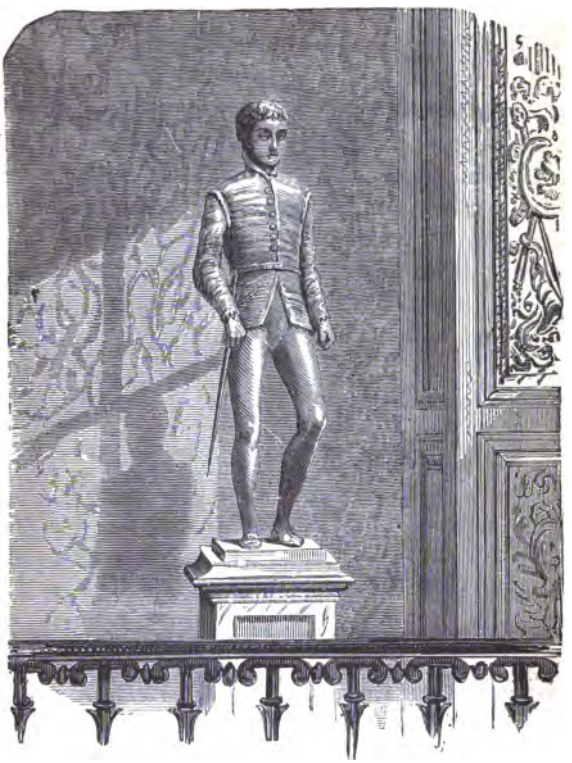
This process, invented by an Englishman named Parker, and applied by him in 1841, has since been greatly perfected and simplified, especially in France, where it is always employed as we have described. Generally, the entire statue is produced by this process; but when there are members, such as arms, more or less isolated from the rest of the body, they are reproduced separately, because the arrangement of the wires would otherwise be too complicated.

Usually, the mould is made of two portions, strongly attached together by copper wires, and after the deposit is completed, the two parts of the mould are separated, and the interior metal remains solid, forming the statue itself. In this way, the same mould will serve several times.

On the next page is an illustration of this process, representing a statue of Henry IV. when a boy, produced in silver, from Christofle's moulds. The original is in the Louvre, in one of the halls of the museum of sovereigns. This is one of the most beautiful reproductions that have been made.

The soldering of the different parts together, when such is requisite, is done in different ways. Silver and tin are generally used for this purpose.

When the soldering is finished, the surface is cleaned with acid, and at the line of junction a



Statue of Henry IV., reproduced by Galvanoplasty.

kind of trough is made with putty, which is filled up finally with the metallic solution. Into this liquid is introduced the positive wire of the battery, while the statue communicates with the nega-

tive pole, and the metal is deposited upon the solder. It will thus be seen that we make use of the galvanic deposit not only to solder, but to hide the solder and make the part exactly like what is around it.

DIFFERENT REPRODUCTIONS.

The principal use of galvanoplastic art, is to reproduce, with scrupulous fidelity, the model from which the mould has been made. If the mould is in relief, the deposit will be sunk; but upon this first reproduction we can prepare other moulds to bring out the objects in relief. It must not, however, be forgotten that the chief condition of success is to make good moulds, and that if these have the slightest defect, those defects will be repeated and exaggerated in the casts. Thus only when the original object itself can be used in the bath, is there an opportunity of certainly avoiding all imperfections. For example, if we wish to reproduce the seal of a letter, we heat a small wire, which we apply to the wax at the margin. Afterwards, the surface of the seal is metallized, and the whole plunged into the bath, where the deposit is formed. When taken from the bath, the seal is separated from the reproduction, and there is thus obtained a perfect cast of it in relief. This is said to be the means of which agents charged with the work of unsealing suspected letters formerly made use. After being read, the letters were resealed

with the galvanic duplicate, and there remained no evidence of the violation of the secrets of the correspondence.

Generally, the moulds of the objects are taken, and the work performed as described. When the objects to be taken are flat, such as medals and bas-reliefs, they are hung in the middle of the bath, so that they may be coated horizontally. If the bas-reliefs are of very great size, and present bold points, the positive wire is made to send ramifications into the hollows, or that pole is terminated by a metallic plate, reproducing the form of the object and placed opposite it.

It was by this process that the bas-reliefs of the column of Trajan were produced. In the month of July, 1864, these bas-reliefs, obtained in galvanic copper, were placed in the halls of the Louvre, to be permanently exhibited. This precious work, sent forth from the factory of M. Oudry, near Paris, was executed from plaster casts sent direct from Rome, and moulded upon the column itself, in 1861–62. Already, many times, and especially under the reign of Francis I. and Louis XIV., the attempt was made to transport into France those bas-reliefs in which the interest was incalculable; but the attempts were futile.

MANUFACTURE OF CANDELABRA.

In 1865 there could be counted in Paris about 30,000 jets of gas giving a light equivalent to that

of 300,000 candles, whereas, a hundred years ago, the capital of France was illuminated by only 6,000 candle lanterns.

The wonderful facility with which candelabra or chandeliers are manufactured has certainly much contributed to the increase in their number. They are covered with galvanic copper; this is the principal work of the factory of M. Oudry, at Auteuil, near Paris.

A chandelier is formed of two parts, the foot and the stem; the lighting apparatus being manufactured separately. After being cast, the pieces are varnished with a mixture of resinous substances. Copper does not adhere to iron; and the galvanoplastic bath, being always strongly acid, violently attacks iron, corrodes it, and renders it unfit for use. When, therefore, it is necessary to copper-plate a piece of iron, it must first of all be dipped into a bath of cyanide. This increases the expense.

Oudry's varnish makes copper adhere to cast iron. The various parts of the candelabra, being varnished, are covered with a coating of plumbago, and carried to the bath of sulphate of copper. Dipped into this, the copper is deposited gently, and the thickness increases more and more. At the end of a week a layer of considerable thickness is obtained, and two portions of the candelabrum are then sent off separately to the bronzing room.

The bronzing of all articles in galvanic copper is intended to preserve them from verdigris, and to

give them a pleasant appearance. Exposed to damp air, the copper is soon covered over with a green rust. Without speaking of the danger of leaving this poison publicly exposed, an unpleasant effect is produced by the articles becoming spotted over with red or green blotches. To prevent this, all articles in copper, whatever they may be, are bronzed—such as statues, candelabra, bas-reliefs, etc. This process consists in rubbing the copper surface with an oil containing a particular substance which chemists call sulpho-hydrate of ammonia. It has the property of making the copper surface completely unalterable by the air.

Many layers of bronzing are put upon chandeliers, in order to give them the color which they generally present, instead of the red color of the galvanic copper. Bronzing is the last process; the candelabra being then finished. It only remains to put the pieces together, and fix them by a strong solder. A chandelier manufactured in the manner described costs about fifty dollars, and lasts about ten years.

CHAPTER III

DIFFERENT USES OF ELECTRO-PLATING.

THE processes of electro-plating may be applied whenever we wish to cover any object with copper. Whatever be the material employed, we can make it a conductor of electricity by coating it with plumbago, and dipping it into the bath with requisite care. All substances, such as silk, fruit, leaves, and stems, are thus transformed into metal. The leaves of the most delicate flowers have, in this way, served to form jewels, perfectly imitating nature. More than this; upon one occasion there was presented at the Academy of Science, at Paris, the body of an infant that had died at its birth, covered with a layer of copper. This very eccentric fact shows, at least, that nothing limits the powers of copper plating.

In many circumstances, however, there is a necessity, as we shall indicate, for slightly modifying known processes; but though in different manufactories the form of the apparatus may vary somewhat, as well as the manipulation, the operations are fundamentally the same.

ELECTROTYPING.

Copper plating has become the active auxiliary of printing; it serves to reproduce wood cuts in such a way that, of the same design, we can produce numerous examples. Formerly, impressions were taken from the wood itself, in the condition that it came from the engraver; but it was found that the design soon became worn and spoiled; the lines lost their sharpness, and after a time the engraving had to be done over again. Afterwards, stereotyped plates of type-metal were made. The process is now different; moulds of gutta percha or beeswax are pressed upon the wood; the mould is then metallized and placed in the copper bath. The duplicate obtained is washed and properly finished, fixed upon wood or metal, and used at once as a plate graven on copper. If the deposit is very light, the copper is very hard, and one can print from sixty to eighty thousand impressions of this picture.

These different manipulations have not increased the price copper plate engravings. Before the invention of copper plating, an atlas, consisting of eighty large maps, cost about ninety dollars—an exorbitant price, and within the reach only of the owners of libraries. A single map engraved on wood cost about ninety dollars; and, in the case of wood drawings, only 2,000 impressions could be printed, the last of which displayed defects. By means of copper plating, on the other hand, we reproduce the plate as often as we wish, without having recourse to the expense of re-engraving; and all the

impressions are as perfect as the original design, cut by the artist. At the present time the same atlas would not cost forty dollars. This reduction results entirely from the circumstance that printing is no longer limited by the wood engraving.

In the reproduction of stereotype plates, or of printing types, it is seldom that recourse is had to electric processes, unless the plates are to be very much used, or contain engravings and delicate lines. Nearly all pictorial papers are now electrotyped.

Certain designs require to be produced with the utmost fidelity; for example, checks, postage stamps, and bank notes. A design copied from an original always differs from it in some respects, and will not deceive even unpracticed eyes. It is necessary that in these cases copies should be produced, quite identical with the model. This is how it is done. A postage stamp we shall say is engraved with care upon a steel plate, and a perfect copy of the die obtained by pressing a plate of lead upon it. This plate of lead forms the matrix of the postage stamps, and upon it the workmen operate.

The leaden plate is used as a mould, and many galvano-plastic copper casts are taken from it, each a perfect copy of the original die, and as capable of being used in the printing press. One hundred of these copies, arranged so as to form a plate, are used for printing the sheets.

When in consequence of long use one of these plates is worn or defaced, another is made from the first leaden mould. Rarely is it necessary to have recourse to the die.

GALVANIC ENGRAVING.

Galvanic engraving, invented by Smee, gives the same effects as ordinary engraving; but is more beautiful and clear than engraving by means of aqua fortis. Upon a plate of copper, wholly covered by a thin coat of insulating varnish, a design is drawn by marking through the varnish to the metal. This plate is put into a bath of copper and placed at the positive pole. The negative pole is formed by a plate of metal of the same dimensions. When the current passes, the copper dissolves gradually at the bottom of the lines marked on the positive plate, where the insulating varnish has been removed, and is deposited upon the negative plate. At the end of the operation the design is found reproduced in the neatest and most regular manner.

The Prince of Leuchtenberg has reversed Smee's method. He draws a design in oily ink upon a plate of copper. Placing the plate in the copper bath, at the positive pole, all the surface, except the lines protected by ink, is bitten down by the acid. The lines themselves remain and form the picture.

DAGUERREOTYPE PLATES.

For a long time efforts were made to engrave upon daguerreotypes, in such a way as to be able to print in ink the images obtained by the sun.

Galvano-plating has resolved this problem also. Daguerreotype proofs are obtained upon a plate of polished silver. The shadows are produced by the brilliant surface of the silver itself, and the lights by the small drops of mercury attached to the silver. The thicker the coating of mercury is, the clearer will be the print. Divers means have been successfully employed to engrave the plate. Mr. Grove has succeeded in applying to this purpose Smee's method of engraving. The daguerreotype plate is covered on its posterior face with a varnish of gum lack, which protects those parts of the plate that are not to be operated upon. The plate is then plunged into a bath below the positive pole. The bath is composed of chlorohydric acid, dissolved in water. Whilst the silver is quickly attacked by the acid, the mercury is attacked but slowly. The negative pole, which is composed of a plate of platinum of the same dimensions as the plate to be engraved, is placed very near to the latter. The current passes, and at the end of about thirty seconds the daguerreotype plate is drawn out of the bath and the silver alone is found to have been attacked. It is then washed in a solution of water and ammonia, and the plate displays a design upon which the shadows are represented by indentations, and the lights by lines upon the plates.

CONCLUSION.

Eight hundred years before our era, the Greek philosopher Thales, of Miletus, observed that yellow

amber acquired by friction the singular property of attracting light bodies. Around this first sufficiently established fact, many other similar facts gradually clustered. Afterwards, when in the course of ages, by a chain made up of a mixture of lucky chances and laborious experiments, it was discovered that this primitive electricity manifested itself under a variety of forms, and produced other effects, mechanicians and philosophers set themselves to work, and sought to evoke parts of this new force according to the particular objects they had in view.

Some saw that electricity produced in one place, could be moved so as to be able to act in another place; from this have been deduced all the telegraphic systems. Others seeking in electric currents the means of affecting our organs and producing physiological effects, arrived by a way more or less indirect at the knowledge of constructing powerful machines, capable of many important applications. Others again, seeing that electricity put bodies in motion, attempted to transform it into a motive power, and wasted their energies in seeking impossibilities, not quite absolute, but nevertheless actual, if only relative. Others have only demanded light and heat from electricity, and have found them in abundance. Finally, others have employed this agent to decompose solutions and obtain chemical results.

All these advances, all these material discoveries do not date further back than forty years. Flowing from a simple fact observed by Thales, science, like the rivers that come down from unknown mountains,

conceals its sacred origin. It appears at first only as a feeble rill; for a long time it flows between narrow bands; gradually it enlarges and deepens; then, suddenly increased from mysterious sources, it widens its banks, overflows, and, flooding the world, divides into an infinity of canals, and spreads plenty and happiness throughout regions far removed from its source.

APPENDIX.

(SEE BOOK SECOND, CHAPTER I.)

THE tendency of European writers, and especially the French, to ignore the labors of American philosophers and inventors, is strikingly illustrated in the chapter referred to. A brief history of Induction, and Induction apparatus, as developed in the United States, in connection with what is called the Induction Coil, will serve to show who are the real discoverers and inventors of this wonderful machine.

The importance of the induction coil is not overrated in the chapter alluded to. It may be safely said that no other instrument has equalled it in the splendor of the effects it is capable of producing, or in the importance of the uses to which it has been applied.

After six years' experimenting upon induction currents, Professor Faraday, in 1831, announced his results as follows: "I could obtain no evidence by the tongue, by spark, or by heating of fine wire or charcoal; nor could I obtain any chemical effects." Only the galvanometer could tell that an induction current existed. By means of an electro-magnet he obtained a slight spark from charcoal points; by a very powerful loadstone he succeeded in convulsing a frog's legs. This was the extent, at that time, of the progress of that great philosopher in these momentous discoveries.

In March, 1832, Mr. Forbes, of Edinburgh, caused a spark by means of a steel magnet. In June, 1832, Professor Henry, of Yale College, discovered that a bright spark could be obtained from a *long* wire, especially when coiled into a helix, even when none could be obtained from a *short* wire. No shock was obtained by either of these philosophers.

Early in 1833 Professor Dal Negro said that the separating spark was partly magneto-electric, and would be augmented by coiling the wire around a bar of soft iron.

In December, 1834, Mr. William Jenkins, of England, informed the Royal Society, through Professor Faraday, that he obtained *shocks* through the agency of an electro-magnet, with a *single pair* of plates.

In 1835, Mr. Wagner, of Frankfort, used the first mechanical circuit-breaker. It was used only with a voltaic battery. In the same year Professor Henry discovered that a spiral ribbon, 96 feet long, gave shocks as far as the elbows, with a large calorimotor. In June, of this year, Masson obtained from a *primary* circuit shocks sufficient to kill a cat. Neither Henry nor Masson used *inductive* electricity in their experiments.

While the great philosophers of the Old World were thus groping doubtfully in the twilight on this momentous subject, Charles G. Page, a young medical student of Salem, Mass., without any means of knowing what was done in Europe, was thoughtfully experimenting on this subject, and by May 12th, 1836, had invented the induction coil, and both a mechanical and automatic circuit-breaker of great simplicity and efficiency. Doctor Page exhibited his coil in operation to some of his friends, and, amongst others, to Francis Peabody, of Salem. Soon after this Mr. Peabody went to Europe, and gave to Mr. Sturgeon, publisher of Sturgeon's Annals, England, a description of Doctor Page's experiments and apparatus, giving the credit to Professor Henry instead of to Doctor Page. This was a week or two prior to the meeting of the British Association, in Bristol, where the announcement of Doctor Page's coil and its effects gave a right direction to the studies of the

European philosophers, and the first important impulse on the road of discovery.

The coil used by Doctor Page was made of a copper ribbon, one inch wide and 220 feet long, so arranged as to be a true induction coil, and operated with a single voltaic cell. A short time after his first experiments he lengthened his spiral ribbon to 320 feet, and obtained still better results. The distinction between the coils of Professor Henry and Doctor Page is in two things: 1st, Doctor Page's was much longer than Professor Henry's; 2nd, it was an *induction* coil, while Professor Henry's was not. This was the first instrument ever constructed from which shocks were received from a circuit *exterior* to the voltaic battery circuit. It was by means of this powerful coil that Professor Page was able to demonstrate the identity of thermo and voltaic electricity. He obtained the thermo-electric spark and shock in August, 1836. Antinori and Linari obtained their results in December of the same year, being four months later.

On August 23rd, Professor Callan, of Maynooth College, Ireland, invented the first induction coil in Europe. His plan of obtaining an intensity current from the secondary was *exactly the same* as that adopted by Professor Page.

A full examination of all the facts and dates connected with this most interesting subject shows that Professor Page is the inventor of the first induction instrument capable of giving shocks, and an intensity current from a secondary circuit.

This same instrument has the honor of being the first in the world which passed a spark between charcoal points *before contact*. This was done April 19th, 1837.

The unpleasant part of the subject begins here. Although Professor Page's discoveries are printed in Silliman's Journal as they occur, and in Sturgeon's Annals, in England, the apparatus being described and figured, the English philosophers and inventors appear to entirely ignore his existence. Even Professor Noad, in his London Lectures, while describing an induction apparatus exactly like Page's—the flat spiral being exactly the same length and width, and even

the means of insulation adopted the same, namely, *list*, the whole being manifestly a fac-simile of Page's—nevertheless apparently attempts to claim antecedence to that which he copied.

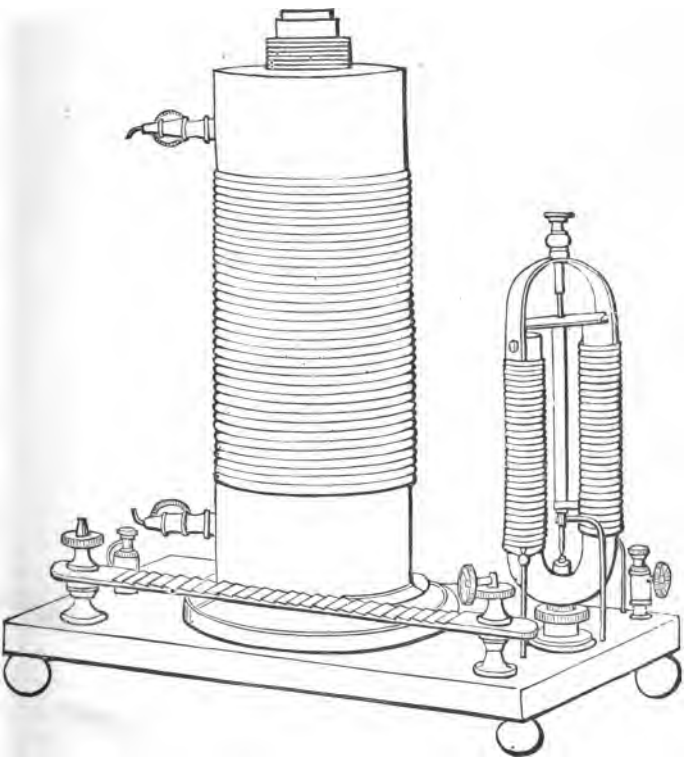
In June, 1838, Professor Page described the first induction coil ever published, in which the secondary and primary coils were completely insulated from one another; and, at the same time, with the secondary wound upon the primary, but insulated from it. His "compound-magnet and electrotome," though finished in April, was not published till November. Its effects were powerful and novel. It would not only give dangerous shocks, but would send a spark *before* contact, and, on suddenly separating the electrodes, the spark was half an inch long. It would decompose water, diverge the gold leaves of the electroscope without a condenser, and charged a Leyden jar at every contact.

Another of these beautiful and ingenious instruments, constructed, as was the last, by Mr. Davis, is figured here. In every case Professor Page anticipates the European inventors. Indeed, they merely repeat his experiments, and often without naming him. In 1850 he constructed a coil so powerful that a *bar of iron, one thousand and forty pounds in weight*, was suspended within it, vibrating in the air without visible support, and the separating spark was *eight inches* in length.

Soon after these results were published, M. Ruhmkorff, a skillful instrument maker of Paris, improved the insulation of the European instruments, and changed their form, so as more nearly to resemble Page's coils. With this apparatus he obtained sparks about one eighth of an inch long. Fizeau discovered the effects of the condenser soon afterwards, and Ruhmkorff attached it to his coil. This immediately increased the length of the spark, and attracted public attention to his instruments. In 1856, Hearder, of England, obtained sparks one inch in length, and soon after obtained them four inches long. All these results were obtained by superior insulation, and by winding the second-

ary coil in several sections instead of in one piece. This method was employed long before by Professor Henry. The insulation by shellac was fourteen years old.

The only improvement now possible appeared to be attain-



Page's Induction Machine.

able by increasing the length of the secondary wire. The English had set the example to the French, and very soon the limits were reached. Beyond a certain size of coil the electricity breaks through the insulation and the coil is

ruined. European philosophers and machinists were baffled. Ruhmkorff looked with despair upon the ruins of one which he had attempted to make more powerful than any other. French science and skill, as well as English, was exhausted without attaining the results desired.

In this condition of the subject, Mr. E. S. Ritchie, an accomplished and skillful scientific mechanist of Boston, looked upon and conquered the difficulty. He says: "I then devised a mode of winding the wire in planes, perpendicular to the axis, alternately running from the inner to the outer, and from the outer to the inner circumferences of the helix, insulating between the strata; and, in July, 1857, instruments were made, giving sparks twelve inches in length." Until July, 1859, neither Ruhmkorff nor Hearder had succeeded in obtaining a spark more than three or four inches in length.

Now we have a sad case of injustice on the part of Ruhmkorff and the French scientists. In 1858, Professor McCullough states that he ordered one of Ruhmkorff's coils, informing him that Mr. Ritchie, of Boston, held himself ready to surpass it, whatever its power might be. In 1859 he visited M. Ruhmkorff, and urged him to accept the challenge in vain. Supposing that he would be happy to compare his coil with Ritchie's, and desiring to gratify him, in July, 1859, he sent one of Ritchie's seven inch spark coils to M. Ruhmkorff, at the same time ordering from Mr. Ritchie one of the most powerful coils he could make.

M. Ruhmkorff *dissected* the seven-inch coil sent him by Professor McCullough, and constructed one like it for the Polytechnic School. Having availed himself of Mr. Ritchie's method, without giving him credit, his coils now equalled Mr. Ritchie's, giving sparks thirteen to sixteen inches long. The French scientific journals immediately expatiated on the excellences of Ruhmkorff's coils, awarding him all the credit of the improvements, and thoroughly ignoring Ritchie, although many of them had seen his instruments in operation, and were fully conversant with the facts of Ruhmkorff's plagiarism, and Ritchie's right to the credit of the construction.

Not satisfied with this amount of injustice, the French Institute awarded the Emperor's prize of fifty thousand francs to M. Ruhmkorff, as the *inventor* of the "coil bearing his name," although one, at least of the members of the commission, Jamin, was fully conversant with all the facts connected with the introduction and imitation of Ritchie's coil, and was present when Ritchie's coil was exhibited. *M. Ruhmkorff accepted the francs.*

In view of all the facts, it is certainly proper for American scientists to drop the name of Ruhmkorff from the designation of the coil, and either to substitute the names of the real discoverer and inventor, or to confirm the modest appellation of *Induction Coil*, used now by Mr. Ritchie himself.

Ignorantly, perhaps, (although that is a hard insinuation here,) Professor Tyndall attributed to Joule, of England, a discovery made several years before Joule's experiments, and published in Silliman's Journal, by Professor Page. The learned and eloquent Professor Tyndall attributed the discovery of the vibration of "Trevelyn's bars" by galvanism, and also the rolling of metallic cylinders upon rails by the same agency, to George Gore, Esq., of England, although the same discoveries were announced in Silliman's Journal, by Professor Page, more than eight years before Mr. Gore's experiments. To recapitulate merely the discoveries and inventions of American philosophers and mechanics, often used but not acknowledged by European machinists and experimenters, would require many pages. Enough has been done to show that European scientific history is not reliable.

A more full account of the matters treated in this appendix may be found in the "History of Induction," published by the "Intelligencer Printing House," Washington, 1867. The foregoing statements are mainly condensed fragments extracted from this "History."

In reflecting upon the history of electrical discovery since 1836, it is certainly remarkable that only *one* really important addition to inductive apparatus originated in Europe—Fizeau's condenser—all the others are of American origin. Contrary to the English estimate of American character, it

is the philosopher of the Western world who has had the constancy of purpose to pursue, with undeviating step and untiring energy, the path of discovery which his more complete understanding of the nature and bearing of this difficult subject so early led him to select. That the reader may have a better view of at least this one case, we copy from the before mentioned History of Induction, the following list of the inventions and discoveries of Professor Charles G. Page, in the different departments of science concerned in the development of the properties of inductive electricity.

INDUCTION APPARATUS.

1. The first galvanic apparatus, with an intensity secondary coil.

2. The first induction apparatus by which shocks were obtained from a secondary *circuit.*

3. The first induction coil, in which the battery current was caused to pass through only a portion of the circuit, while the shocks and other indications of intensity were taken from the whole circuit.

4. The first induction apparatus by which shocks and other indications of electricity of high tension, were obtained from a purely secondary circuit, exterior to the primary circuit.

5. The first induction apparatus in which the secondary circuit exceeded the primary circuit in length.

6. The first induction apparatus in which the secondary circuit was exterior to the primary circuit.

7. The first induction apparatus with a secondary circuit adapted to medical purposes.

8. The first application of a self-acting circuit-breaker to an induction coil of any kind, with or without a secondary circuit.

9. The first application of a mechanical circuit-breaker to an induction coil, consisting of a primary and secondary circuit.

10. The first discovery of the electrostatic properties of the secondary current.

11. The valuable discovery that the intensity of the secondary current is greatly increased by breaking the primary circuit under a poor conducting liquid. This was rediscovered eighteen years afterwards, in Europe, by Poggendorff and Foucault.

12. The first organized apparatus for the exhibition of the electrostatic properties of the secondary current.

CIRCUIT-BREAKERS.

13. The first mechanical circuit-breaker used with an induction coil, was by M. Masson, of France; but the first automatic or self-acting circuit-breaker, used with an induction coil, was by Professor Page. Also,

14. The first circuit-breaker, used with an induction coil, having a primary and secondary circuit.

15. The first *independent* automatic circuit-breaker used with an induction coil.

16. The first *attached* circuit-breaker was by Professor McGauley, of Ireland; but the first adjustable, automatic circuit-breaker, whether *independent* or *attached*, was by Professor Page. Also,

17. The first mercurial circuit-breaker.

18. The first automatic *attached* circuit-breaker, in which the retractile force of the hammer was adjustable.

19. The first spark-arresting circuit-breaker.

20. The first *attached* circuit-breaker which combined the means of adjusting the retractile force of the hammer and its distance from the magnet.

21. The first use of an automatic circuit-breaker with an induction coil for remedial purposes.

22. No novelty or improvement in principles of construction has yet been made in circuit-breakers that is not embraced in the fifteen different kinds invented by Professor Page, prior to 1840.

ELECTROSTATIC COIL, ETC.

23. The first electrostatic coil was the invention of Professor Page, Also,

genius of Cyrus W. Field, the Atlantic Telegraph, which, sending its throbbing pulses through the million [illegible] in sympathy with it throughout the world, speak [illegible] good will to the great brotherhood of nations.—A.

II.

THE POSTAL TELEGRAPH.

(see page [illegible])

The Report of the Postmaster-General of the [illegible] States for the year 1871, strongly urged upon Congress [illegible] purchase and control of the telegraph lines [illegible] and without doubt such a transfer will be [illegible] tant day. The Secretary says that "in Sweden, [illegible] Russia, Bavaria, Italy, Turkey, Greece and Spain, [illegible] vantages have been gained by making the telegraph [illegible] of the public postal system; while in Switzerland, [illegible] the Netherlands, Prussia, and France, [illegible] ances and improvements have been [illegible] the policy of governmental control has been [illegible] It remained for Great Britain, however, [illegible] test of the public system as compared with [illegible] of corporations and companies of private [illegible] Referring to an elaborate report of Mr. [illegible] pears that the average cost of [illegible] 1s. 1d. (twenty-six cents,) against an average [illegible] the completion of the transfer in February, [illegible] (thirty-eight cents,) showing [illegible] one third. In the first week [illegible] of messages (exclusive of [illegible] from all stations, was [illegible] March, the number had [illegible]

24. The principle on which the present success of the electrostatic coil depends, involving the principle of Fizeau's condenser, was first discovered by Professor Page.

25. With the exception of Fizeau's condenser, the electrostatic coil is an American invention, and the so-called Ruhmkorff coil was commenced and perfected in the United States, Professor Page developing the electrostatic properties, and Edward S. Ritchie, of Boston, consummating the perfection of the instrument, to an extent far exceeding anything known in Europe.

26. Professor Page also first identified the *magneto-electric* current with static electricity, and first indicated how the magneto-electric machine could be made to produce sparks.

27. Professor Page also was the first to obtain sparks from thermo-electric apparatus.

With this remarkable catalogue of American discoveries and inventions in the department of inductive electricity, we might well afford to close. As in telegraphic apparatus so in inductive electricity, American genius bears away the palm. But there is one more triumph to be named—the most stupendous in the whole history of telegraphy—the Atlantic cable. Let it be remembered that this greatest of all the triumphs of telegraphic enterprise is due, by universal consent, to the business foresight, energy, genius and perseverance of an American, Cyrus W. Field. But his name is not so much as mentioned by our author, in his history of the laying of that very cable! What more could he do to show how far away from candor, prejudice may lead an able and interesting writer.

The following brief summary will not be considered as claiming too much, viz.:

American science and mechanical and business genius have furnished the best and most widely used telegraphic apparatus in the world—Morse's.

It has given the scientific world, through Professor Page and E. Ritchie, the induction coil—an instrument of such terrible power, that the most experienced philosophers handle it with awe.

It has given to Europe and America, through the business

genius of Cyrus W. Field, the Atlantic Telegraph, which, sending its throbbing pulses through the million fiery fingers in sympathy with it throughout the world, speaks peace and good will to the great brotherhood of nations.—A.

II.

THE POSTAL TELEGRAPH.

(SEE PAGE 147.)

THE Report of the Postmaster-General of the United States for the year 1871, strongly urged upon Congress the purchase and control of the telegraph lines in this country, and without doubt such a transfer will be effected at no distant day. The Secretary says that "in Sweden, Norway, Russia, Bavaria, Italy, Turkey, Greece, and Spain, great advantages have been gained by making the telegraph a part of the public postal system; while in Switzerland, Belgium, the Netherlands, Prussia, and France, where modern appliances and improvements have been more thoroughly utilized, the policy of governmental control has been fully vindicated. It remained for Great Britain, however, to give a practical test of the public system as compared with the management of corporations and companies of private stockholders. Referring to an elaborate report of Mr. Scudamore, it appears that the average cost of inland messages is now about 1*s.* 1*d.* (twenty-six cents,) against an average cost prior to the completion of the transfer in February, 1870, of 1*s.* 7*d.*, (thirty-eight cents,)showing a reduction in price of nearly one third. In the first week after the transfer, the number of messages (exclusive of news and Press messages,) forwarded from all stations, was 128,872; in the week ending 31st March, the number had risen to 160,775. The total num-

ber of messages forwarded in the three quarters, to 31st December, 1870, was 7,563,015.

"The companies, before the telegraph transfer to the government, sent news to 306 subscribers in 144 towns only in the United Kingdom; the postal telegraph sent news to 1,106 subscribers in 365 towns. The companies sent news to 173 newspapers only; the postal telegraph sent news to 467 newspapers; showing an increase of 221 in the number of towns to which news was sent, an increase of 800 in the total number of subscribers for news, and an increase of 294 in the number of newspapers taking news. There was, moreover, a vast increase in the quantity of news transmitted. The companies sent, during the session of Parliament, nearly 6,000 words of news daily; during the remainder of the year they sent nearly 4,000 words daily. The postal telegraph sent, during the session of Parliament, in behalf of the news associations, nearly 20,000 words of news daily; and during the remainder of the year, nearly 15,000 words daily. The postal telegraph also transmitted from 15,000 to 20,000 words daily for the ordinary newspaper correspondents, and seven newspapers rented special wires during the night at the uniform rate of £500, instead of rates ranging from £750 to £1,000, as before. Two other wires were about to be rented to newspaper proprietors at the close of the year, and many more could have been rented if the Department could have spared them."

"By an official statement received from the British office the number of messages for the week ended September 23rd, 1871, is shown to be 256,456, against 189,636 for the corresponding week of last year."

The importance of such a transfer to our government can scarcely be overestimated. Already the military and weather signal messages of the government are very numerous. In the report of Secretary Belknap, of the War Department, for the year 1871, we are told that "in the month of October the display of cautionary signals, announcing the probable approach of storms, was commenced, for the first time in the United States, at twenty ports upon the lakes, and At-

lantic and Gulf coasts. These signals are arranged to be displayed at any hour of the day or night, upon the receipt of telegraphic orders from Washington.

"While the service has been rapidly organized and pressed to these results, each step has been taken only when the public mind seemed to be educated and prepared for it and the public necessity demanded it. The average time of the receipt by telegraph of the reports and observations made simultaneously from all the stations throughout the United States has been forty-five minutes. The average time elapsing between the moment at which telegrams were sent to the office at Washington from the most distant stations to that at which the deductions are made, published, and issued to the press, has been ninety minutes."

The meteorological importance of simultaneous reports of the weather at distant points can only be realized in the lapse of time; but it is claimed that great damage to commerce has already been prevented by the storm signals, and it may be safely predicted that discoveries in the laws of storms, and other phenomena, will be made through the means of these reports, which many people at the present day would consider marvellous.

THE END.

A NEW AND VALUABLE SERIES

For Readers of all Ages and for the School and Family Library.

The Illustrated Library

OF

TRAVEL, EXPLORATION,

AND ADVENTURE.

EDITED BY

BAYARD TAYLOR.

The extraordinary popularity of the ILLUSTRATED LIBRARY OF WONDERS (nearly *one and a half million* copies having been sold in this country and in France) is considered by the publishers a sufficient guarantee of the success of an ILLUSTRATED LIBRARY OF TRAVEL, EXPLORATION, AND ADVENTURE, embracing the same decidedly interesting and permanently valuable features. Upon this new enterprise CHARLES SCRIBNER & Co. will bring to bear all their wide and constantly increasing resources. Neither pains nor expense will be spared in making their new Library not only one of the most elegantly and profusely illustrated works of the day, but at the same time one of the most graphic and fascinating in narrative and description.

Each volume will be complete in itself, and will contain, first, a brief preliminary sketch of the country to which it is devoted; next, such an outline of previous explorations as may be necessary to explain what has been achieved by later ones; and, finally, a condensation of one or more of the most important narratives of recent travel, accompanied with illustrations of the scenery, architecture, and life of the races, drawn only from the most authentic sources. An occasional volume will also be introduced in the LIBRARY, detailing the exploits of individual adventurers. The entire series will thus furnish a clear, picturesque, and practical survey of our present knowledge of lands and races as supplied by the accounts of travellers and explorers. The LIBRARY will therefore be both entertaining and instructive to young as well as old, and the publishers intend to make it a necessity in every family of culture and in every private and public library in America. The name of BAYARD TAYLOR as editor is an assurance of the accuracy and high literary character of the publication.

TWO VOLUMES NOW READY.

JAPAN.

Illustrated with a finely engraved Map and more than thirty beautiful Wood-cuts.

WILD MEN AND WILD BEASTS.

BY LIEUT.-COL. GORDON CUMMING.

The following volumes are also well advanced, and will be issued at about monthly intervals:—

ARABIA. **SOUTH AFRICA.**

The volumes will be uniform in size (12mo), and also in price ($1 50 each).

☞ *Catalogues, with specimen illustrations, sent on application.*

CHARLES SCRIBNER & CO., 654 Broadway, N. Y.

A NEW SERIES OF

The Illustrated Library of Wonders,

ENLARGED IN SIZE, IN A NEW STYLE OF BINDING, AND EDITED BY PROMINENT AMERICAN AUTHORS.

The extraordinary success of the ILLUSTRATED LIBRARY OF WONDERS has encouraged the publishers to still further efforts to increase the attractions and value of these admirable books. In the new series, which has just been commenced with THE WONDERS OF WATER, the size of the volumes is increased, the style of binding changed, and the successive volumes are edited by distinguished American authors and scientists.

The following volumes will introduce

THE SECOND SERIES OF THE

ILLUSTRATED LIBRARY OF WONDERS.

MOUNTAIN ADVENTURES. (39 Illustrations.) Edited by J. T. HEADLEY.

WONDERS OF ELECTRICITY. Edited by Dr. J. W. ARMSTRONG, President of the State Normal School, Fredonia, N. Y.

WONDERS OF VEGETATION. (Over 40 Illustrations.) Edited by Prof. SCHELE DE VERE.

WONDERS OF WATER. (64 Illustrations.) Edited by Prof. SCHELE DE VERE.

WONDERS OF ENGRAVING. (34 Illustrations.)

THE FIRST SERIES OF

The Illustrated Library of Wonders

Comprises Twenty Volumes, containing over 1,000 Beautiful Illustrations.

These twenty volumes in cloth, or in half roan, gilt top, are furnished in a black walnut case for $30.00 (the case gratis), or they may be bought singly or in libraries, classified according to their subjects as below, each 1 vol. 12mo. Price per vol. $1.50.

WONDERS OF NATURE.

	No. Illus.
THE HUMAN BODY	43
THE SUBLIME IN NATURE	44
INTELLIGENCE OF ANIMALS	54
THUNDER AND LIGHTNING	39
BOTTOM OF THE SEA	68
THE HEAVENS	48

6 Vols. in a neat box, $9.

WONDERS OF ART.

	No. Illus.
ITALIAN ART	28
EUROPEAN ART	11
ARCHITECTURE	60
GLASS-MAKING	63
WONDERS OF POMPEII	22
EGYPT 3,300 YEARS AGO	40

6 Vols. in a neat box, $9.

WONDERS OF SCIENCE.

	No. Illus.
THE SUN. By Guillemin	58
WONDERS OF HEAT	93
OPTICAL WONDERS	71
WONDERS OF ACOUSTICS	110

4 Vols. in a neat box, $6.

ADVENTURES & EXPLOITS.

	No. Illus.
WONDERFUL ESCAPES	26
BODILY STRENGTH & SKILL	70
BALLOON ASCENTS	30
GREAT HUNTS	22

4 Vols. in a neat box, $6.

☞ Any or all the volumes of the ILLUSTRATED LIBRARY OF WONDERS sent to any address, post or express charges paid, on receipt of the price.

A descriptive Catalogue of the Wonder Library, with specimen illustrations, sent to any address on application.

CHARLES SCRIBNER & CO., 654 Broadway, N. Y

AUG 2 9 1930